A PRACTICE OF
THORACIC SURGERY

BY

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PREFACE

In choosing the title of this book I deliberately selected the words A Practice rather than The Practice of Thoracic Surgery A real system of thoracic surgery requires several volumes and several authors to achieve any degree of comprehensiveness In attempting to clear my views as to my own practice I have reluctantly discarded descriptions of obsolete techniques and views being only too conscious that by the time this volume appears, many of these may have been revived even if in altered form for this is common in the history of surgery which is always punctuated by advances real or ill-conceived and retreats which may be wise or misguided In many places no doubt the obvious is reiterated with sickening monotony and the difficult is ignored I have attempted to stress the points of difficulty that puzzled me when I first encountered them and to answer the questions so often put to me by physicians general practitioners or young surgeons in the course of their training whether they be studying abdominal or thoracic surgery I have failed to summarize the vast literature on thoracic surgery and many omissions are obvious In a developing field of surgery information is passed largely by word of mouth and I owe a great deal to conversations at the meetings of the Association of Thoracic Surgeons of Great Britain and Ireland. I must apologize for unrecorded acknowledgements to surgeons whose opinions have frequently guided me At all events I can say that this book is not for my own colleagues in the thoracic field for all in it is known to them but I should like to dedicate it to the members past and present of that Association and ask their indulgence for any imperfection

The thoracic surgeon is dependent largely on the help of his colleagues and I acknowledge with gratitude the encouragement and assistance that I have received from a wide circle of physicians surgeons radiologists and pathologists There is a danger of thoracic surgery becoming segregated from Teaching Hospitals if this trend progresses such isolation will be injurious to undergraduate and post-graduate clinical education as well as to thoracic surgery Professor F A. R Stammers has always arranged for its inclusion in the Department of Surgery in the University of Birmingham and I acknowledge with gratitude his constant help and influence I am especially grateful to Dr Brian Taylor who in addition to developing and encouraging the spread of thoracic surgery in this area has written the introduction and provided helpful criticisms of many sections of the book I must thank Professor Melville Arnott Professor of Medicine in the University of Birmingham for his constant advice and encouragement and his colleagues Dr K. W Donald and Dr Paul Davison for the sections respectively on Lung Function and Cardiac Catheterization also Dr Roy Astley radiologist to the Children s Hospital Birmingham for a thorough and lucid account of Angiocardiography Mr Robert Brain a loyal colleague and friend and now on the staff of Guy s Hospital, has provided invaluable assistance in many sections notably those on post-operative treatment and the nutrition of the surgical patient

I am indebted to Mr T F Doe clinical photographer to the Queen Elizabeth Hospital Birmingham for the major portion of the photographs and reproductions of radiographs which has entailed a great deal of work on his part I must also thank Mr J G Williamson A I B P A.P P S clinical photographer to the Children s Hospital Birmingham for providing the work illustrating conditions in childhood

I acknowledge with pleasure the assistance given by the Genito Urinary Manufacturing

Company for their kind loan of blocks to illustrate the beautiful instruments which have a world-wide fame of their own

Many colleagues have generously placed their clinical material at my disposal, in addition to those already mentioned I must thank Dr J E Geddes, the head of the Birmingham Tuberculosis Service, Dr Clifford Parsons of the United Birmingham Hospitals, Dr D J. McIlveen of Hill Top Thoracic Surgical Hospital and my surgical colleagues S J MacHale and Miss Ruth Richardson for much help I owe a great deal of gratitude to many surgical registrars and house officers who have provided a great stimulus to me, and to many members of the nursing profession for something much more than devoted service to my patients

Miss Mary Jones, a former house surgeon, has indefatigably checked and re-checked the references, and I am grateful for her untiring and painstaking efforts

My present registrar, Mr Keith Roberts, has made the index for me and I am grateful to him for the hours of devoted labour he has given to this task The method of numbering the illustrations has been copied quite unashamedly from Dr Paul Wood's book on "Diseases of the Heart and Circulation" (Eyre and Spottiswoode)

But for Miss Mary Bowers, my former secretary, this book would never have reached the printers not only did she type the manuscript, but she provided most of the drawings presented and laboured with the greatest energy and good humour over a difficult task, and this expression of thanks is quite inadequate To Miss Margaret Wilkie, my secretary, I am grateful for her great help over the present edition

I must also acknowledge my deep gratitude to my wife for her constant encouragement while writing this book and for her unfailing and unselfish support during the toils of its production

In this second edition, I have attempted to bring the material up to date In the last few years, great advances have been made in the surgery of the heart and great vessels, the position in pulmonary tuberculosis has altered radically so that perplexing difficulties have arisen over the question of selection of patients for surgery The steady increase in lung cancer has provided a challenge which is being met better than many doctors think, as in most centres over 30 per cent of the patients who have undergone pneumonectomy or lobectomy are alive five years later Such a survival rate must encourage all to seek early diagnosis of this serious disease Newer views on the oesophagus and the treatment of its disorders are many. In this edition, I have attempted to supply information on these changing fields of thoracic medicine.

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INTRODUCTION

By A BRIAN TAYLOR, MD FRCP

Physician to the United Birmingham Hospital and to the Birmingham Regional Thoracic Surgical Centre

The development of thoracic surgery during the past 30 years has been one of the most striking and exciting features of medical progress in this century—a period when progress has been fast and remarkable in many fields Chest injuries in the first world war and the effects of the influenza pandemic after it, set the stage and in this country Morriston Davies Tudor Edwards and Roberts were the leading actors to rise to the occasion From them the mantle has fallen on a modern generation which has not stood still, but has extended the field and advanced the technique that this branch of surgery offers At this moment it is wise to survey the position that has been reached and to take stock Mr d Abreu has done this in his book—both by describing the widest aspects of thoracic surgery and by critically reviewing the values of the methods and techniques from his own wide experience

Mr d Abreu is particularly well fitted for this task. He has worked with and enjoyed the intimacy of all the leading thoracic surgeons in this country His contacts in Europe and America have been numerous and frequent both during the war and in civil practice His experience in the Welsh National Memorial Tuberculosis Service in which he was fortunate to work under the kind and friendly guidance of Mr Morriston Davies and Sir Clement Price Thomas before the war in the Army throughout the whole war and in many of the most active fields and in his development of thoracic surgery in the Midlands since the war have given him exceptional experience of which he has taken the fullest advantage. He therefore writes with the authority of an experienced surgeon, a brilliant teacher and a keen supporter of research both practical and theoretical into all the disorders within the chest

Accompanying and making possible all these advances have been the notable extensions of the ancillary subjects and methods. The physiology of cardio-respiratory function is perhaps hardly to be described as ancillary it is fundamental though it is only in recent years that it has caught up and accompanied practical therapeutics Radiology perhaps has pride of place in having brought an understanding of thoracic function and disease which the traditional methods of clinical examination could never by themselves achieve Advances in anaesthesia and particularly the closed circuit methods have enabled thoracic surgeons to embark safely on operations within the chest One must also include the help given by nursing and physiotherapy in the management of thoracic disease and the pre- and post-operative treatment

It will be apparent that the thoracic surgeon is in the centre of a large team of experts—specialists in particular methods who have all advanced with him in knowledge research and technique This book amply supports this basis of the team and gives credit to the numerous members of the team The physician in the team may think of himself in several ways—as the collector and diagnostician to bring the patients to the team at the right time and in the right way as the co-ordinator of the members of the team perhaps as their controller and guide In practice he is probably the adviser and student This admirable state of affairs has been achieved in Birmingham and Mr d Abreu s thesis underlines the co-ordinated working of his team

At the Queen Elizabeth Hospital in Professor Arnott s Department of Medicine research

nd practice in cardio-respiratory physiology has kept the feet on the ground The stimulus of teaching, the wide opportunities for research and research workers, and the influence University and Hospital departments with their critical and helpful staffs, have supported organization Fortunately, too, the closest liaison has been reached with the development of thoracic surgery under the Birmingham Regional Hospital Board, who have recently opened a special hospital for thoracic surgery In the last analysis, the help given to the patients with thoracic disease is the criterion of the success of the method, and with this ctive organization now in its stride one can watch this with confidence

PART I

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

INTRODUCTION

A surgeon entering into a new field of surgery has the privilege and advantage of starting at a point already reached by his masters and teachers In 1934 largely through the kind encouragement of the late Professor Lyle Cummins the Professor of Tuberculosis in the University of Wales I started the study and practice of thoracic surgery Conversations with colleagues convince me that many members of our profession believe that thoracic surgery is of recent origin an error that is corrected if the original work of the pioneers is studied. In 1934 a wide literature was available and an account of the surgery of the chest up to that date would fill a large volume Assuming that much of that knowledge has become part and parcel of the modern practice of surgery I have attempted in this book to outline the present position of a subject that continues to advance in a most exciting way in the physiological as well as the technical field After much strenuous work by pioneers such as Sauerbruch Lilienthal Alexander Morriston Davies Roux Murphy Tudor Edwards J E H Roberts and a host of others a rational treatment had evolved for the care of empyema and certain forms of chronic pulmonary tuberculosis Shenstone and Janes (1932) had developed a one-stage technique for lobectomy in bronchiectasis and the tourniquet form of that operation now abandoned, had given an enormous impetus to surgery Total pneumonectomy for bronchiectasis and for neoplasms of the lung developed rapidly greatly helped by notable improvements in thoracic anaesthesia and in the readier application of blood transfusion Operations across a free pleura became commonplace The outbreak of war in 1939 found the newer surgical techniques ready to be applied to the war wounds of the chest a better understanding of the physiological disorders of the wounded chest and later the availability of the new antibiotics enabled thousands of chest casualties to make full recoveries The lessons learnt in the conflict were applied coincidentally to other thoracic diseases and in spite of the confusion of the days thoracic surgery made great progress Those of us who were engaged solely in military surgery were astonished but none the less delighted to find that a host of new techniques had to be learnt on returning to civilian surgery In resection of lung tissue the addition of dissection lobectomy to the already established method of individual ligation of the great hilar structures for the eradication of malignant disease of the lung represented the greatest advance for it could be applied to the common diseases of pulmonary tuberculosis bronchiectasis and chronic lung abscess Its superiority over the older cumbrous and unsafe method of tourniquet lobectomy was obvious The logical extension of this type of resection operation was the development of safe methods for the removal of segments and subsegments of the lung when these were the seat of isolated eradicable disease The coincident improvements in anaesthesia and in the pre and post-operative phases were such that published series of resection for bronchiectasis often reported a mortality rate of under one per cent

The application of thoracic surgery to the treatment of lung cancer, pulmonary tuberculosis, bronchiectasis and chronic lung abscess was no longer limited by hesitancy on the part of physicians to refer patients in a way that was noticeable before the war, but by the lack of thoracic surgeons and anaesthetists and by the poverty of institutional provision for the care of such patients

The oesophagus had ceased to be regarded as a deeply placed, unapproachable organ and new chapters had been written on the management of its neoplastic disease and in the detection and relief of non-malignant lesions such as oesophagitis, peptic ulceration, cardiospasm and diverticular formation The free incision of the diaphragm by the thoraco-laparotomy incision of the military surgeon for the treatment of many thoraco-abdominal wounds found an equally favoured civilian use for the approach to carcinoma of the stomach, for portal hypertension and for splenectomy

The persistent ductus arteriosus, the coarcted aorta, the mitral, aortic, tricuspid and pulmonary valves have all been subjected to surgical treatment the treatment of congenital obstruction to the outflow tract of the right ventricle and at the pulmonary valve level has become commonplace by indirect method (the Blalock anastomosis) or direct method (the Brock operation) and blind and open closure of septal defects are being used increasingly The surgeon has called in the aid of hypothermia and mechanical extra-corporeal circulations in these fields and in other cardio-vascular disorders so that open cardiac operations have achieved a permanent place in surgery The thoracic surgeon is now concerned with the treatment of pathological and disordered physiological states of the cardio-vascular, respiratory, alimentary and neurological systems, he must therefore be a general surgeon working in a wide region, he must be able to examine endoscopically the larynx, trachea, bronchus and oesophagus, thoracoscopy though scarcely ever used for division of adhesions in artificial pneumothorax helps in the diagnosis of some thoracic lesions The recognized surgical approaches may include the exploration of the neck and abdomen as well as of the thorax, splenectomy or thyroidectomy may be done as individual operations or as part of more extended procedures such as total gastrectomy for cancer or the excision of malignant growths of the upper end of the oesophagus

The pre-war tendency to separate the surgery of pulmonary tuberculosis from that of other thoracic disease has receded with the increased adoption of resection operations in the treatment of pulmonary tuberculosis, and this has emphasized the similarity of techniques required in the management of both groups of diseases

The general principles of surgery naturally govern the practice of chest surgery and the thoracic surgeon must have had an adequate post-graduate training in general surgery before concentrating on this work, the application of recent advances in chemotherapy, resuscitation, the maintenance of correct fluid and electrolyte balances, and physiotherapy, are adopted vigorously in major thoracic surgery, and the meagre reference to them in this book implies that the readers have an understanding of them and because they are not peculiar to this branch of surgery In recent years surgical techniques and aims have become more physiological and the particular position of thoracic physiology requires a more lengthy exposition than the anatomical and pathological accounts presented The advances in thoracic physiology have been too extensive to allow an adequate account of them to be presented and only an outline of that fascinating adventure can be given

Through empirical trial and error and with the support of the anaesthetist, at least a working knowledge of the physiology of the open pneumothorax has been achieved, but only in recent days have the scientific approaches of the physician engaged in the study of human respiratory physiology been applied to our craft, centuries of perplexing errors and fears

in the management of wounds of the thorax have led at last to a simple solution of the treat ment of the sucking open wound and infection of the pleural cavity in the recent conflic the application of physiological knowledge insisted on the early closure of the sucking woun and after that excision of the damaged area of the thoracic parietes which surgical experien has shown to be the essential prophylaxis against crippling infection but the story d not end there and the insistent demand of physiological principles called for early reso to methods that would improve lung function hence the early aspiration of traumat effusions the decortication of the strangled lung the use of physiotherapy the warding o of anoxia by rational oxygen therapy and the use of blood transfusion, all measures design to correct a disorganized physiology The technical advances in lung or lobe excision the treatment of pulmonary tuberculosis and cancer and in the surgical endeavours improve the function of the physiologically and anatomically deformed or diseased hea are not enough

Surgeons who stand on the threshold of the surgery of the lung today will not fi prestige and fame in treading the easy pathways that were open to the older members this Association. We enjoyed for a brief period the heyday of rapid technical developme that follows the initial conquest of a new territory Advance in the surgery of the lu will not be derived from technical experience alone ' (Churchill, 1949)

The investigation of the cardio respiratory system by modern methods has passed t stage of providing fundamental basic conceptions and is being increasingly applied to t treatment of the thoracic surgical patient as will be seen by a reference to the chapte written by Dr Donald Dr Davison and Dr Astley which they have kindly revised this edition

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CHAPTER I

ANATOMICAL CONSIDERATIONS

Accurate diagnosis and the execution of safe surgical techniques depend largely on the unravelling of distorted anatomy in the thorax the anatomical picture presented at thoracotomy for the removal of a lung with an early carcinoma differs vastly from that seen when extreme pleural and pulmonary disease has apparently destroyed all anatomical planes and dispositions as in chronic empyema, advanced bronchiectasis or tuberculosis But the dissection of planes through organized fibrous tissue ultimately displays an anatomy of remarkable regularity and nowhere is this more noticeable than in the deliberate exposure of the vessels and bronchi of a lung, lobe or segment preparatory to its resection But notable abnormalities do present these provide a host of conditions in the lungs, heart, great vessels, oesophagus, mediastinum and diaphragm, which frequently require surgical treatment and are discussed in the appropriate chapters

Exact descriptions of bronchial anatomy are provided by Brock (1946, 1950), and the recent attempt to obtain international acceptance of a universally recognized nomenclature for the various broncho-pulmonary segments (*Thorax*, 1950) have simplified the descriptions of lung operations False ideas on facts so fundamental as the location of the great fissures of the lung have only slowly been abandoned The great oblique fissure of the lungs, formerly considered to start posteriorly at the level of the fourth rib or the third thoracic spinous process, is actually at a much lower level, usually that of the fifth or sixth rib, a piece of knowledge vital to those planning a thoracic approach to the various segments and lobes of the lung

THE ANATOMY OF THE LUNG

Although most lungs show a clear division by definite fissures between the lobes, such lines of cleavage may be obliterated in whole or part by well-defined bridges or by inflammatory adhesion of lung tissue , areas of true fusion are seen best between the apex of the lower lobe and the posterior segment of the upper lobe and between the upper and right middle lobes In surgical resections of lobes or segments this continuity of lung parenchyma between one lobe and another may hamper the dissection and exposure of hilar vessels, but once the vessels and the appropriate bronchi (lobar or segmental) have been isolated and divided the segments of lung to be removed can be peeled out along the relatively avascular segmental or lobar boundaries If the lung is kept fully ventilated by the anaesthetist after the bronchus of the area to be removed has been clamped and divided, the line of demarcation between the aerated and non-aerated areas will be obvious unless pathological air drift is present (see p 10) In such operative dissections the intersegmental vein is an excellent guide to the excision as it follows the line of the boundary between the segment to be removed and its neighbour

The bronchial and vascular supply to the main lobes

The different anatomical arrangements of the two lungs have surgical significances , in general, pneumonectomy is technically easier on the left side than on the right because

of the greater length of the vessels and main bronchus and because the superior vena cava partly overlies the right main pulmonary artery on the other hand the removal of the right upper lobe is simpler than that of the left where the arterial supply is arranged more awkwardly from a surgical point of view because of the sweep of the left main pulmonary artery behind its bronchus These apparent anatomical difficulties are however readily overcome in both instances if dissection of the perivascular sheath is thorough and adequate



Fig 1 1



Fig 1 2

Fig 1 1—Lateral radiograph of a child.
The interlobar fissures show up well after a previous pleurisy Note especially the posterior projection of the great fissure.

Fig 1 2—Segmental collapses due to infected muco-pus.
Bronchoscopy was negative for neoplasm and the segments rapidly re-expanded. The area collapsed are the apex of the right lower lobe and the anterior and posterior segment of the right upper lobe. Note the position of the apex of the lower lobe.

The bronchial supply (Fig 1 3)

(*A*) *The left side* The main stem bronchus from the carina of the trachea to the upper lobe orifice is much longer and has a more oblique course than the right-sided one The upper lobe bronchus leaves the outer side of the main stem and divides into the apical the posterior the anterior and lingular segmental bronchi often the apical and posterior bronchi have a common stem and this has led to the description of an apico-posterior segment in some works The left intermediate bronchus is that portion of the main bronchus between the origin of the upper lobe bronchus and the branches to the lower lobe and is extremely short because the lower lobe apical bronchus arises much on the same level as the lingular bronchus when exposed in the main fissure as in the operation of left lower lobectomy and lingulectomy The subdivisions of the bronchus into segmental branches is considered later

(*B*) *The right side* The right main stem bronchus leaves the carina more vertically than the left one and is wider and shorter The upper lobe bronchus leaves it at a distance less than 2 cm from the trachea, is more horizontal in direction than the corresponding bronchus of the left upper lobe and lies at a higher level than the main pulmonary artery; hence its older description, now discarded, as the eparterial bronchus As the bronchus descends it is covered in part by the main stem of the pulmonary artery which is partially covered anteriorly by the superior pulmonary vein The middle lobe bronchus arises from the anterolateral surface of the main stem and is usually opposite the bronchial opening of the apical segment of the right lower lobe as that leaves the posterolateral surface of the main bronchus The main bronchus then passes on to divide into the four segmental bronchi of the lower lobe

THE NOMENCLATURE OF THE BRONCHO-PULMONARY SEGMENTS

Various authors in presenting their individual accounts often gave different names to the segments, so that a confused nomenclature evolved A recent attempt at an internationally accepted classification was reported to the Thoracic Society of Great Britain (1950) and this nomenclature will be adopted here. As it displaces many commonly accepted terms some of these will be given in brackets

The Right Lung

The three lobes of this side have ten main segments distributed as follows

(*A*) *The right upper lobe*

1 Apical segment
2 Anterior segment (Anterolateral or pectoral)
3 Posterior segment (Posterolateral)

(*B*) *The middle lobe*

4 Medial segment (Superior)
5 Lateral segment (Inferior)

(*C*) *The right lower lobe*

6 Apical segment (Dorsal lobe, superior segment)
7 Medial basal segment (the cardiac lobe)
8 Anterior basal segment
9 Lateral basal segment (Mid-basal segment)
10 Posterior basal segment

(These are " major " segments · subdivisions occur of which perhaps the most commonly described is the sub-apical segment of the apical division of the lower lobe)

The Left Lung

This has nine main segments

(A) The left upper lobe

Upper division i e that portion of the lobe bronchus before the lingular bronchus has left it has three segments

1 Apical segment } (Apico posterior bronchus)
2 Posterior segment }
3 Anterior segment (Anterolateral or pectoral)

(B) The lingula (Lower division bronchus)

4 Superior segment
5 Inferior segment

(C) The left lower lobe

6 Apical segment
7 (Absent when compared with right side i e no cardiac lobe)
8 Anterior basal segment
9 Lateral basal segment (Mid basal segment)
10 Posterior basal segment

The chief alterations in this nomenclature are that the terms medial and lateral are preferred to internal and external , that the use of axillary has been abandoned and that dorsal lobe is no longer used as descriptive of the upper segment of the lower lobe No classification is likely to please everyone and the one quoted fails to indicate certain other segments that are at times additionally present but it has certain merits of simplicity and is of value to the clinician

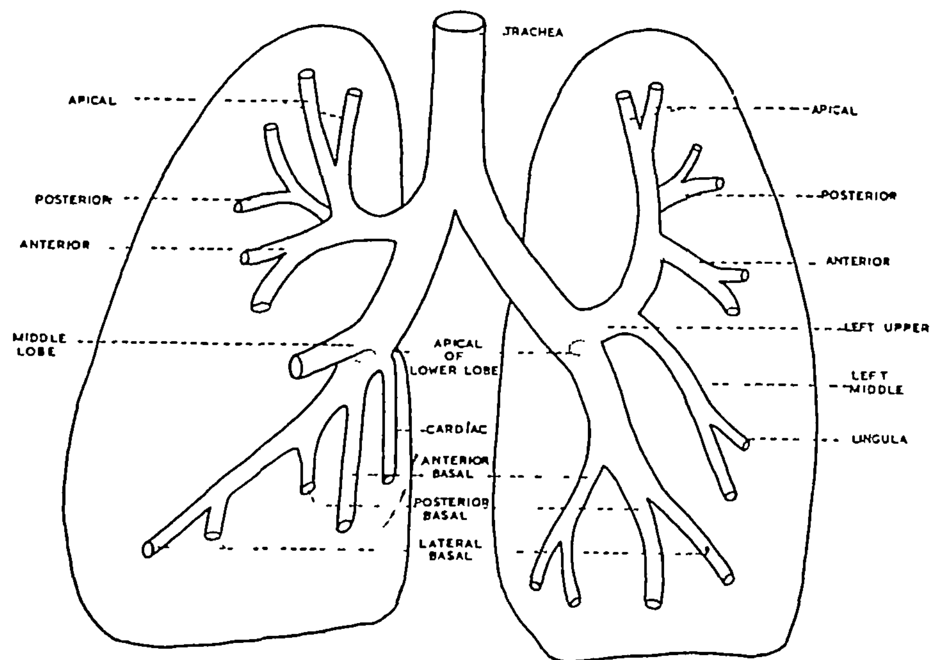
Anatomy of the broncho-pulmonary segment

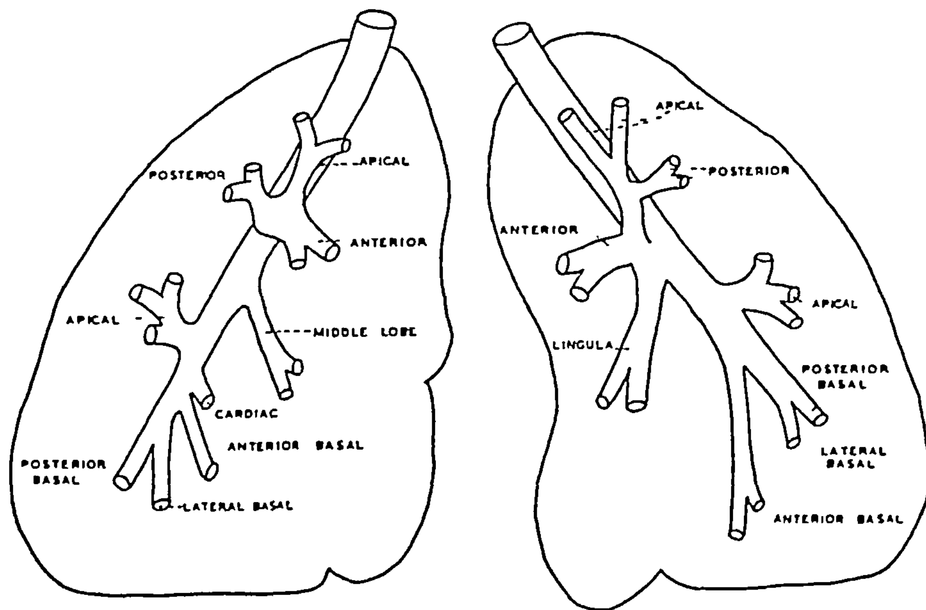
The stimulus given to the development of better techniques for the removal of diseased lobes by the careful anatomical expositions of workers such as Brian Blades and Kent (1940 1942 and 1943) was followed by many clear publications on the anatomy of the hila of each individual segment and the surgical removal of isolated diseased segments became an established procedure This conservative resection first practised on the lingula segment of the left upper lobe (Churchill and Belsey 1939) was soon adopted in the treatment of bronchiectatic and tuberculous segments of a diseased lung so that unisegmental or multi segmental excisions avoided the unnecessary sacrifice of healthy lung tissue a conservatism of especial value when the disease is bilateral (Pilcher 1941 Overholt 1948)

Each segment has a fairly constant anatomical arrangement of its bronchus and artery but the veins and lymphatics have frequent communications with those of the adjacent lung areas

Intersegmental veins

Because of the important influence these have on the technique of segmental resection a special account of their anatomy is necessary Boyden and Scannell (1948) described clearly the existence of these veins in addition to each individual segment having a clearly defined vein blood passes to another vein that lies in the plane between two adjacent segments If this vessel is ligated during a segmental resection the venous return of the healthy adjacent unit is largely obstructed so that passive congestion follows and this may be sufficient to produce post-operative haemoptysis It is not always easy to define the trunk of this intersegmental vein at the hilum and in the actual operation it is wiser whenever possible to divide the artery and bronchus apply gentle traction to them and so open up





(a)

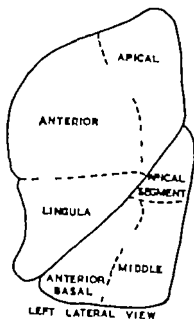
Fig 1 3

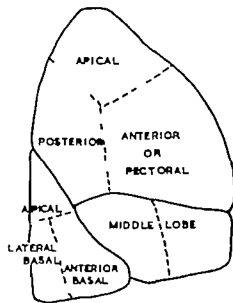
(*a*) Diagrammatic representation of the bronchi the upper drawing represents the anterior view, the lower diagram illustrates the lateral aspects

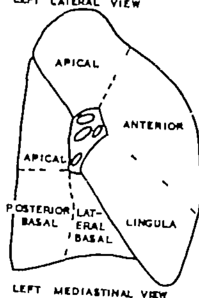
(*b*) Shows the segments of the left lung as seen from the lateral and mediastinal aspects

(*c*) Segments of the right lung as seen from the lateral and mediastinal aspects

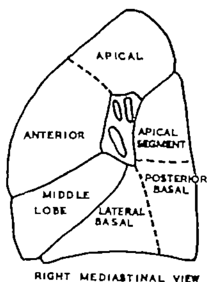
(*d*) Segments of the right and left lungs seen from the anterior aspect


APICAL
ANTERIOR
APICAL SEGMENT
LINGULA
MIDDLE
ANTERIOR BASAL
LEFT LATERAL VIEW

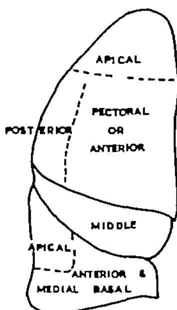

APICAL
POSTERIOR
ANTERIOR OR PECTORAL
APICAL
MIDDLE LOBE
LATERAL BASAL
ANTERIOR BASAL
RIGHT LATERAL VIEW


APICAL
ANTERIOR
APICAL
POSTERIOR BASAL
LAT-ERAL BASAL
LINGULA
LEFT MEDIASTINAL VIEW

(b)


APICAL
ANTERIOR
APICAL SEGMENT
POSTERIOR BASAL
MIDDLE LOBE
LATERAL BASAL
RIGHT MEDIASTINAL VIEW

(c)


APICAL
POSTERIOR
PECTORAL OR ANTERIOR
MIDDLE
APICAL
ANTERIOR & MEDIAL BASAL


APICAL
ANTERIOR
LINGULA
AN TERIOR & MEDIAL BASAL

(d)

the intersegmental plane As the plane is defined by a combination of traction, blunt and gentle scissor dissection, both the segmental and intersegmental veins become obvious if the field is kept clear of blood At this stage the segmental vein can be isolated, divided and ligated and any small branches to the intersegmental vessel divided so that its main trunk is left patent (Chamberlain and Ryan, 1950) If the segmental artery and bronchus are isolated and divided, traction away from the hilum enables the particular segment to be peeled out of the surrounding lung tissue During this separation the main segmental vein is seen emerging from the area to be resected and after its ligation and division the segment can be drawn out until it is held only by a covering of visceral pleura which is readily divided to allow complete removal The raw areas of the contiguous lung tissue bleed a little from the rupture of small communications with the intersegmental veins and if there is a positive intrabronchial pressure, air and anaesthetic gases will bubble out of damaged alveoli for a little while, but since there is no intersegmental communication of bronchi this soon ceases

Air drift

The extended use of lobar and segmental resections has demonstrated with certainty that in conditions of disease, at all events, collateral ventilation can take place from lobe to lobe or segment to segment independently of the bronchial route From time to time when bridges of lung tissue connect one lobe to another, as so frequently happens, a portion of the lobe to be resected can be filled with air if the anaesthetist increases the pressure of gases in the bronchial tree *after* the bronchus of the lobe has been isolated, clamped and divided Churchill's observations (1949) support the claim of van Allen and Lindskog that collateral ventilation can take place between adjacent broncho-pulmonary segments The drift of air from alveoli of one segment to another probably takes place only when entrapped air is present as a result of partial obliteration of the bronchioles producing emphysema and as a mechanism adapted to deal with abnormally high intra-alveolar tensions, and to fulfil a space-occupying function

DETAILS OF SOME SEGMENTAL "HILA"

The lingula segment

This segment is a frequent one to be resected, usually in combination with a left lower lobectomy for bronchiectasis in about 60–80 per cent of examples of bronchiectasis of the left lower lobe the lingula is also involved The bronchus to the segment usually leaves the lower surface of the left upper lobe bronchus about 1 5 cm from its commencement but this is highly variable as often demonstrated by a pre-operative study of the bronchogram It may proceed in a direct line from the main bronchus and exceptionally from the anterior basic bronchus Rarely the bronchus may be a separate stem of the main bronchus

The artery arises from the anterior surface of the main pulmonary artery at a lower level than the last branch to the posterior segment of the upper lobe and on a slightly higher level, or opposite to the origin of the posterolaterally directed vessel proceeding to the apical segment of the left lower lobe The lingular artery lies lateral to the segmental bronchus which is exposed after the vessel has been ligated and divided The vein lies anteromedially to the bronchus and drains into the superior pulmonary vein

The apical segment of the lower lobe

Resection of this segment may be indicated in the treatment of tuberculous disease or for bronchiectasis confined to it it may be spared when the remainder of the lower lobe is being sacrificed for bronchiectasis restricted to the basal segments

If the fissure between the upper and lower lobes is exposed by dissection and adequate retraction the main pulmonary artery will be seen pulsating in its sheath free opening of the sheath exposes the vessel and its first branch to the lower lobe passes backwards and downwards from the posterior surface of the main stem artery lying anterior to the

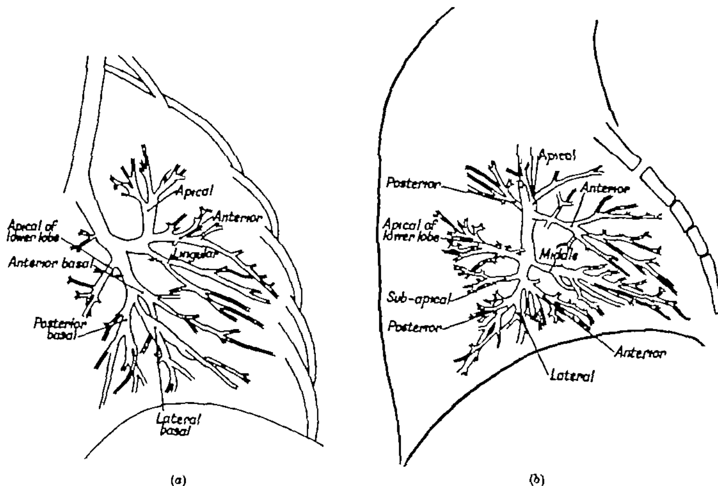


Fig 1 4
(a) Diagram of bronchogram of left lung (right oblique view)
(b) Diagram of bronchogram of right lung (lateral view)

segment bronchus If the lower lobe is retracted medially and the pleura divided in front of its reflection on to the aorta the segmental vein will be seen lying in a plane posterior to and below the bronchus of the segment before it joins the inferior pulmonary vein.

The lower lobe segments

The arteries to these segments (four on the right three on the left) are displayed in the main fissure as they branch off from the main stem below the points of origin of the middle lobe vessel on the right and lingular artery on the left and of the superior segmental arteries to the lower lobe All these arteries lie anterior to the bronchial divisions from which they are separated by thick connective tissue their draining veins join to form the posteriorly placed inferior pulmonary vein

The apical segment of the upper lobe

The artery to this segment is the first branch of the pulmonary artery , if the pleura below the azygos vein on the right or the aortic arch on the left is incised and the apex of the lung depressed downwards, the artery is seen anterior to the medial edge of the main bronchus The segmental vein lies anteriorly and crosses the main downward continuation of the pulmonary artery before entering the principal superior pulmonary vein, and this segment can be resected without any exposure of the major fissure of the lung, on the right side

When the apical segment of the left lung is being resected, if the apex of the lung is held down and the main pulmonary artery is exposed, two branches may be found close together the posterior one of these will supply the apical and the anterior one the anterior segment If, as is common, the left apical and posterior segment are one and to be resected as a unit, the upper lobe is retracted forward and one or two further arteries will require ligation as they leave the main stem artery

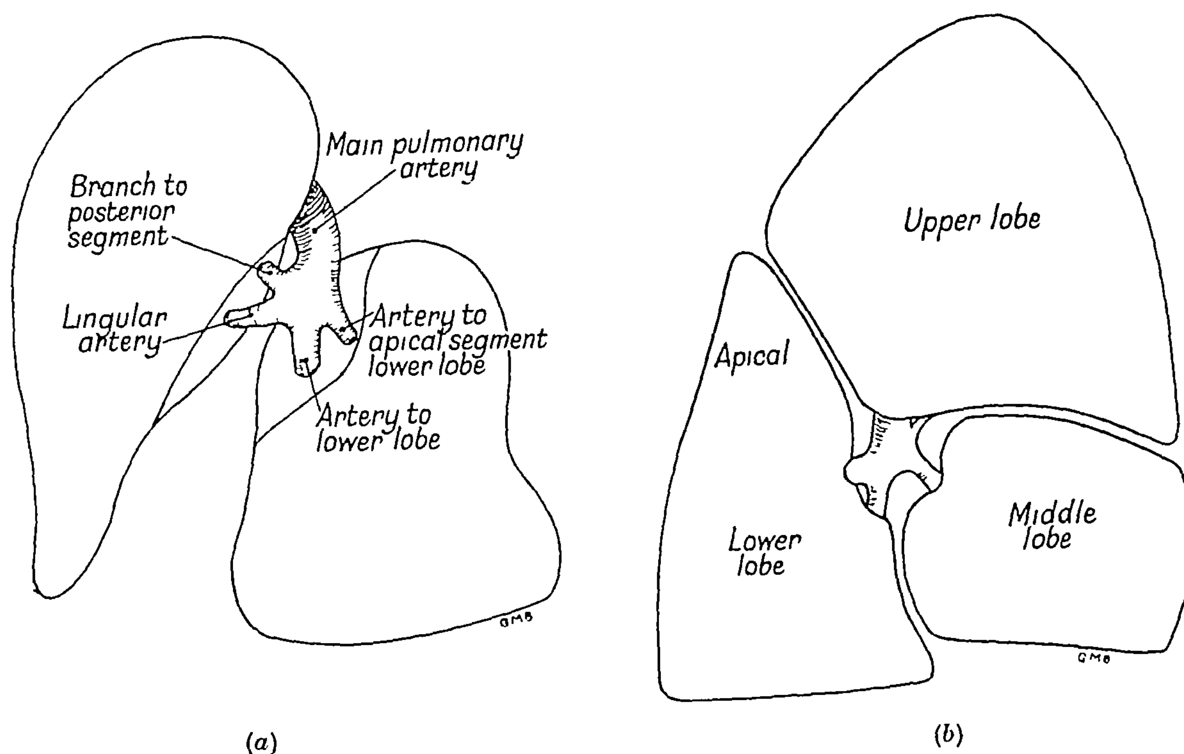


Fig 1 5

(a) Diagram of lingular artery and other arteries of left side
(b) Diagram to show right pulmonary artery As seen in the main fissure

The anterior (pectoral) segments of the upper lobe

(a) *On the right side* The artery to the segment arises from the main pulmonary stem distal to the vessel supplying the apical segment and lies anteromedial to its bronchus, the vein being placed more anteriorly to drain into the upper division of the pulmonary vein A little dissection of lung parenchyma is required, before the rather deeply placed segmental bronchus can be exposed

(b) *On the left side* The artery to this segment usually leaves the anterior surface of the left main pulmonary artery before it curves behind the left main bronchus and is overlapped by branches of the superior pulmonary vein Frequently there is more than one branch.

The posterior segments of the upper lobes

This segment is a common site for tuberculous disease often in combination with cav tion in the apical segment of the upper lobe or of the lower lobe

As it lies posteriorly and laterally it is in contact with the apex of the lower lob which it is often partially fused quite apart from pathological process In resection upper lobe tuberculosis it is frequently noted that disease has spread across the fis to invade the apical segment of the lower lobe

The segmental artery lies deeply, it leaves the main arterial stem as it lies close to main bronchus above the level of the middle lobe or lingular artery and the vessel to superior lower lobe segment It can only be secured when the fissures between the up middle and lower lobe (on the right) have been freely dissected and the pulmonary ar deep in the fissure has been clearly dissected free of its sheath so that the anterior segme artery, the middle lobe artery and that going to the apex of the lower lobe have been displayed During upper lobectomy it is important to see the posterior segmental ar clearly before the bronchus is clamped and divided as it is easily damaged if it has not clearly identified

THE VASCULAR SUPPLY TO THE LUNGS

The pulmonary arteries

Apart from important congenital cardiac abnormalities the course and dispositio these vessels are remarkably constant The fibrous pericardium extends widely over pulmonary arterial trunks though the main stems are extrapericardial especially on t inferior aspect are they in close contact with serous extensions of the pericardial sac both sides a serous extension of the pericardial sac lies between the pulmonary artery the superior pulmonary vein the vestigial fold consisting of the obliterated vein of Mar lying between the two on the left side This forms a consistently stout fibrous band v isolated at operation. These extensions of the sac are of importance in the operatio dissection pneumonectomy or when the pulmonary artery is being cleared as a stag the Blalock operation in congenital cyanotic heart disease if the pulmonary artery is b dissected clear preparatory to its encirclement ligation or temporary occlusion difficu may be encountered if the vessel distal to the line of these extensions has not been me lously cleared of all adventitious tissue A clumsy attempt to clear the posterior wa the vessel may damage the pericardial extensions this is of little moment but the v itself or the superior pulmonary vein may be damaged if the dissection is outside the space within the sheath On the right side there is always a strong band of fibrous ti extending laterally from the pericardium which should be divided before the approac the pulmonary artery is safe In the operation of intrapericardial ligation of vessels carcinoma of the lung these folds which have been fully described by Allison (1946) a great importance (p 275)

The right pulmonary artery appears to be much shorter than the left because overlapped by the bulging superior vena cava but if the latter is gently retracted med after division of the mediastinal pleura there is no difficulty in obtaining a good le for ligation and division

After the right pulmonary artery has emerged from beneath the superior vena

it gives off its large branch to the right upper lobe. The main trunk then passes beneath the superior pulmonary vein which may so overlie it that its ligation and division may be necessary in the course of a right pneumonectomy before the artery can be secured safely, a free division of the fibrous fold lying between the artery and vein makes the ligation of the vein safe and simple. The arterial stem then passes on to the lower lobe where it lies immediately over the bronchus. As it enters the hilum of the lower lobe it gives off a branch anteriorly to the middle lobe and one posteriorly to the posterior segment of the lower lobe. In this area large lymphatic glands are present, particularly above the vessel when they are hypertrophied as the cause or result of bronchiectasis in the middle or lower lobes.

On the left side the main part of the pulmonary artery curves down to the lower lobe behind the upper lobe bronchus and in that position gives off from two to five branches

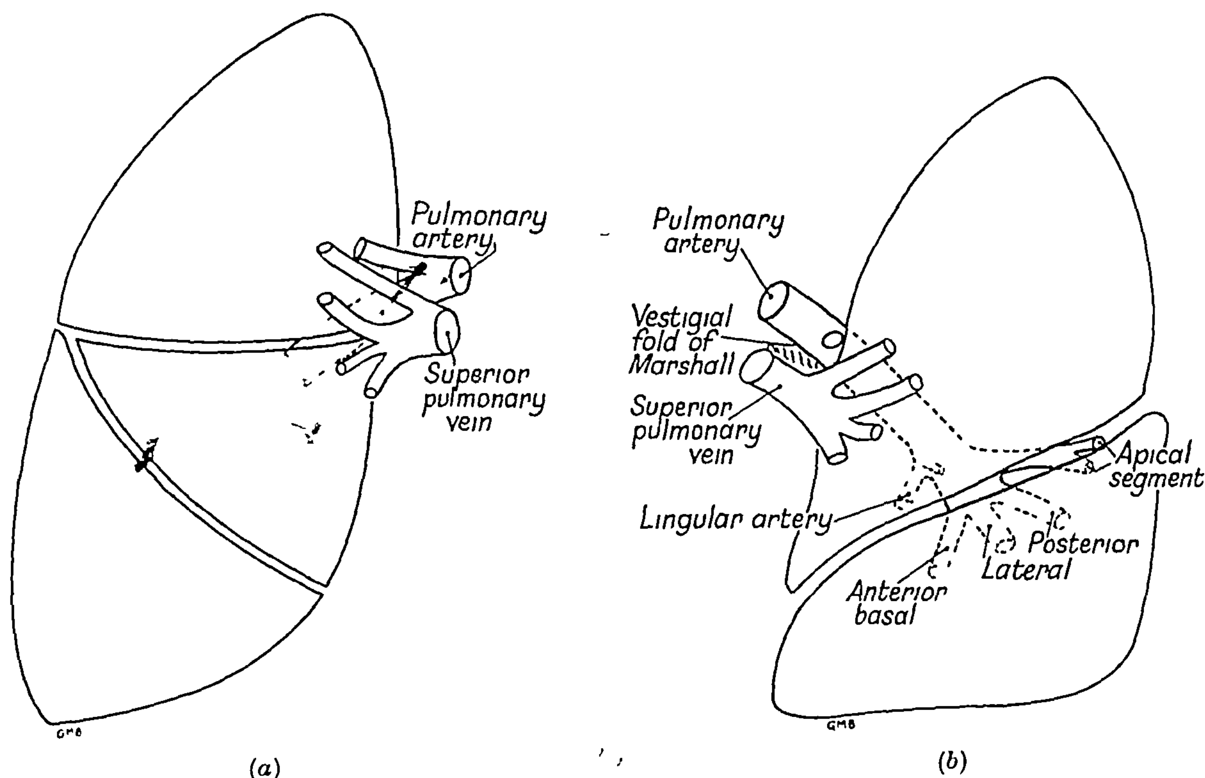


FIG. 1.6

(a) Diagram showing relation of superior vein to right pulmonary artery
(b) Diagram showing relation of left pulmonary artery to superior pulmonary vein

to the left upper lobe. These branches of the artery must be continually in mind during the operation of left upper lobectomy. The vessels are readily visualized if the pulmonary artery is fully exposed by a meticulous dissection of the perivascular sheath right down to the origin of the lower lobe artery.

As the artery proceeds from the lung hilum to the lower lobes in the main fissure it is anterior and slightly above the bronchus which has the vein as a posterior relation. The same relationship usually persists in the broncho-pulmonary segments of the lobes.

Abnormalities of the pulmonary arteries. The important abnormalities of these arteries are noteworthy particularly in congenital heart disease. On one or both sides the main pulmonary artery may be absent, of diminutive size or stenosis may be present at the level of the infundibulum of the main pulmonary stem or in the actual valvular area, information on these points may be obtained by studying the results obtained from cardiac

catheterization and angiocardiography (pp 338 355) When a pulmonary artery is absent a partial functioning of the lung may be possible through a small blood flow carried by greatly hypertrophied bronchial arteries

In transposition of the great vessels the pulmonary artery arises from the left ventricle (in the tetralogy of Fallot the mouth of the aortic stem overrides the septal defect)

Very rarely a pulmonary artery arises from a systemic vessel usually the innominate artery though exceptionally from the lower thoracic aorta the arterial supply of ' dis sociated lung tissue (accessory cystic lobe) by a systemic artery arising usually from the abdominal aorta, will be described later (p 24) Such dissociated lobes may be examples of duplication of the foregut and this may well explain the ectopic blood supply Certain other abnormalities of pulmonary blood supply from the aorta may be capable of embryo logical explanation in connection with faults at different stages in the history of the six pairs of aortic arches (Brown 1950)

To the thoracic surgeon abnormal distributions of the pulmonary arterial branches to the hila of the various segments may cause technical difficulties Perhaps the most important because of the frequent use of the operation of lingulectomy for bronchiectasis is that the lingular artery may give off a considerable branch or branches to the left lower lobe on the right side the main branch to the middle lobe may provide an artery to the inferior surface of the anterior segment of the right upper lobe. The blood supply to the right upper lobe is usually on a simpler plan than that to the left upper lobe but sometimes there are more than three main branches and these should be looked for when the final stages of the detachment of the lobe towards the end of its resection have brought the dissection into the main fissure as careless pulling on these additional vessels may produce a tear of the main stem before it has entered the lower lobe

The thoracic veins

Anomalous venous drainage can effect the pulmonary and systemic circulations There may be a left superior vena cava which drains into the coronary sinus when open operations on the heart are being done such an abnormal vessel must be occluded tempor arily The inferior vena cava may open into the left atrium and may cause cyanosis During the course of an open operation for septal defect I have seen two inferior venae cavae opening into the right atrium Anomalous pulmonary veins may drain into the superior vena cava the innominate veins or the right atrium (into which all or some of the pulmonary veins may drain) or the superior vena cava may be duplicated If all the veins do drain into the right atrium life would only be compatible with a persistent atrial septal defect *, during the operation of right pneumonectomy a pulmonary vein is found occasionally to drain into the superior vena cava and when there is a left superior vena cava one or more pulmonary veins may empty into it

The effects of abnormal venous drainage on the heart When the heart and lungs are normal a pulmonary venous drainage of less than 50 per cent of the lung blood flow into the systemic venous system probably does not lead to cardiac decompensation, but the effects of anomalous venous shunts of less than this may have serious effects when the heart is diseased or when pulmonary lesions develop in that area of the lung that previously functioned normally and when its blood drained into the left atrium *Brantigan* (1947) contends that if at operation for disease of one lobe requiring lobectomy the surgeon

* These anomalous veins must be looked for during the surgical correction of atrial septal defects (see page 405) A complete description has been given by Bailey (195[illegible]

discovers that the venous drainage of the healthy lobe which it was hoped to conserve is *into the major venous systemic circulation*, e g a superior vein draining into the superior vena cava or the innominate vein, this lobe also should be sacrificed in order to diminish the burden on the heart

Although venous abnormalities are met with most commonly in examples of congenital heart disease, they are of importance in diagnosis and treatment of other thoracic conditions and there is evidence that pathological processes have a relative higher incidence when they exist

During lung resection operations, the veins both outside and within the pericardial sac may be abnormal On the right the middle lobe vein not infrequently enters the pericardium as a separate vessel which may join the superior pulmonary vein or proceed as a separate vessel into the left atrium The union of the superior and inferior pulmonary veins into a single trunk composed largely of atrial tissue may provide a puzzling appearance during the operation of intrapericardial dissection pneumonectomy Very rarely there may be one single major vein leading out of a lung and the recognition of such an abnormality in the course of a proposed lobectomy or segmental resection is of obvious significance

The azygos vein during operations such as right pneumonectomy, or exposure of the oesophagus at this level, may require ligation and division to enable the hilum of the lung or the gullet to be fully displayed It may so run that it divides up a portion of the right upper lobe as it indents the lung tissue on its way to join the superior vena cava and so gives rise to an "azygos" lobe The radiological appearances of this abnormality are typical (see Fig 1 7)



Fig 1 7 — Radiograph of azygos lobe

The normal relationship of pulmonary veins does not require detailed description, but surgically the necessity for an exact knowledge of their location is obvious On the right side the superior pulmonary vein so overlies the main trunk of the right pulmonary artery after it has given off its apical branch to the upper lobe that ligation and division may be required before the artery can be cleared and secured The inferior pulmonary vein lies posterior and inferior to the plane of the lower lobe bronchus when the lobe is displaced towards the midline, it is separated from the bronchus to the lower lobe by a notable collection of areolar tissue, the vein is made up of four large tributaries The upper tributary drains the apical segment of the lower lobe and as this branch lies posterior to the main lobar bronchus as it passes on to the basal segments, it must be carefully isolated and protected when the superior segment is being conserved during operation for the removal of the basal segments in bronchiectasis

The bronchial vessels

The systemic arterial supply and venous drainage of the lung plays an important part in disease as well as providing nourishment to the lung parenchyma, the lung will survive ligation

of a main pulmonary artery though with gross but not complete loss of function The bronchial vein drains both into the systemic venous system and into the pulmonary veins if the main pulmonary artery or a lobar one are divided, the bronchial arteries undergo an enormous dilatation and help to carry on part of the function of a pulmonary artery as can be proved by bronchospirometric findings Indeed in congenital cyanotic heart disease where the pulmonary arteries are atretic *life can be maintained entirely through the agency of the bronchial arteries* The bronchial arteries and veins are notably hypertrophied in bronchiectasis it is possible that in mitral stenosis a shunt of blood from the pulmonary system to this systemic system may help to prevent lung oedema through the play of the pre capillary anastomoses

THE PLEURA

A precise knowledge of the dispositions of the pleura is essential especially for the diagnosis and treatment of pleural empyema, pulmonary tuberculosis and subphrenic abscess *The supra-clavicular extension of the dome of the pleura is of practical importance* in the modern type of upper thoracoplasty with Semb s extrafascial apicolysis (see p 205)

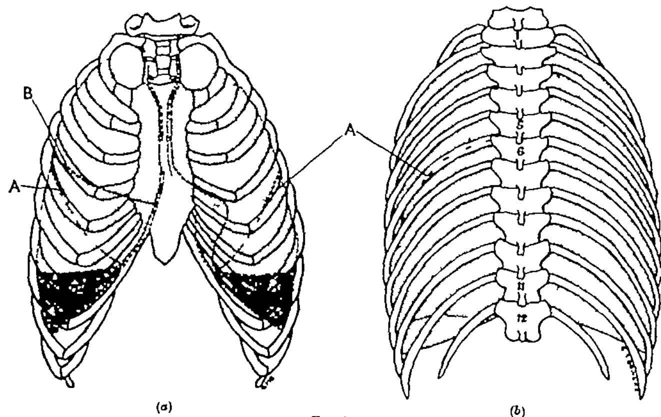


Fig 1 8

(*a*) Diagram of the pleural dispositions as seen antero posteriorly
A indicates the site of the great oblique fissure in relation to the ribs, " B the transverse fissure on the right. The deeply shaded area indicates the position of the lung in inspiration.

(*b*) *Diagram to indicate the pleural disposition seen from the posterior aspect*
The great oblique fissure has only been indicated on the left side.

The normally thin fibro-elastic pleura is attached to the endothoracic fascia differently in the various parts of the thorax Over the apex and mediastinum the pleura can be separated readily in this plane this separation is not so easily achieved laterally or anteriorly where the attachment is firmer but the firmest attachment of the parietal pleura *is* to the dome of the diaphragm and when it is pathologically thickened the attempt to dissect it free is difficult

By a mixture of blunt and sharp dissection the pleura can be separated through the plane of loose areolar tissue in the endothoracic fascial plane in the mediastinum both anteriorly and posteriorly

When thickened by disease the vascularity of the pleura and of its attachments is increased This has an importance in such operations as pleuro-pneumonectomy when the whole pleural sac together with the lung is removed along a line of dissection that proceeds in the plane of the endothoracic fascia (p 248), or in the operation of extrapleural artificial pneumothorax (p 213)

In surgery the pleura carries all the advantages and disadvantages of the peritoneal membrane It has strong powers of repair and can deal with infections that are transient and not due to a continuous leak from intrathoracic organs such as the lung or oesophagus , it readily forms adhesions that may be protective but also destructive of normal physiological process , its gross thickening over the lung or chest wall seriously impairs the normal respiratory physiology, strangling the impaired lung just as the constricted pericardial layers impair and impede the heart in constrictive pericarditis But the pleural membrane itself retains to an astonishing degree a normal anatomy even when massive deposits of fibrin, later organized into fibrous tissue, become incorporated with it through the medium of small blood vessels and this quality enables the surgeons to remove these super-imposed layers of fibrous tissue in the operation of pulmonary decortication in the treatment of empyema, organizing haemothorax and of some lungs that fail to re-expand after artificial pneumothorax treatment

THE LYMPHATICS OF THE THORAX

Appearances at operations on the lungs, oesophagus and mediastinum have amply verified the accurate description of the thoracic lymphatics given by anatomists Of special importance is the enlargement of those glands that lie close to lobar bronchi, for this frequently causes such obstruction that atelectasis develops In tuberculous disease such a collapse most frequently affects the right upper lobe and the middle lobe This type of lymphadenopathy forms a striking feature of the primary tuberculous complex If the glands caseate rupture into a bronchus may cause serious effects (see p 233)

Certain particular groups of glands are of special importance to the thoracic surgeon Of the extrathoracic ones particular attention is paid to the aggregation of nodes above the clavicle which may be infiltrated in patients with carcinoma of the stomach, oesophagus and lungs , exceptionally this group may be attacked by tuberculosis when there is disease of the apex of the lung , occasionally the axillary glands are invaded by malignant tumour masses originating in bronchial carcinoma but this is quite exceptional

The inferior tracheo-bronchial glands are often massively involved by extension from bronchial carcinoma and the normally sharp carina may be converted into a smoother bulge significant of this invasion when viewed through the bronchoscope The glands of the superior mediastinum form a larger group on the right than on the left side and have important connections with those that form a chain above the level of the azygos vein, with the glands lying alongside the upper oesophagus and with the nodes of the left lung hilum. Gross enlargements of these glands on both sides may be a contra-indication to radical excision for carcinoma of the lung or oesophagus Their enlargement, secondary to bronchial carcinoma, may be detected by a careful study of the pre-operative barium

meal studies of the oesophagus Metastases from one lung to the other in carcinoma of the lung is unusual but lymphatic spread to glands of the other hemithorax is common

The glands of the superior mediastinum are perhaps the earliest to be involved by lymphadenoma. Usually there is a small lymphatic gland overlying the ligamentum arteriosum or the persistent ductus arteriosus which is of some surgical significance as when enlarged it may impede the dissection that precedes ligation

In the lower part of the thorax important collections of lymphatic glands envelop the lobar supply both arterial and bronchial to the main lobes *Such glands when enlarged* may not only produce extrabronchial pressure sufficient to cause atelectasis but present surgical difficulties when dissection lobectomy or segmental resection is being undertaken Especially important is the enlargement of lymphatic glands around the middle lobe bronchus



Fig 1 9



Fig 1 10

Fig 1 9—Carcinoma of the oesophagus with gross involvement of the mediastinal glands on both sides. Oesophagoscopy confirmed the diagnosis of carcinoma made on the barium swallow picture and the biopsy was "squamous carcinoma

Fig 1 10—Left pneumonectomy had been performed 8 months before this radiograph was taken At the operation the left superio mediastinal glands were clinically infiltrated by growth the right group of glands are now extensively invaded and there is commencing atelectasis of the right upper lobe.

which is vulnerable to such pressure often causing collapse of the middle lobe A curious fact is that gross inflammatory enlargement of intrathoracic glands rarely proceeds to suppuration though in tuberculous affections caseous material may rupture into a bronchus occasionally this is noted bronchoscopically in epituberculosis of the right upper lobe

Continuing enlargement of glands after a primary complex may cause such serious mechanical complications as rupture into a bronchus tracheal pressure causing stridor or bronchial stenosis causing emphysema that their removal by surgery is necessary (see p 233)

The intercostal spaces contain lymph nodes at the posterior as well as the anterior part of the compartments As is well known the intercostal nodes may be invaded by carcinoma of the breast but they are important also as seats of caseating tuberculosis If such glands break down the resultant abscess may point above the sternum and be regarded

as evidence of tuberculous disease of that bone Caseation and cold abscess formation may also develop in the posterior intercostal glands and track along the subcostal groove of the overlying rib Most so-called tuberculous abscesses of ribs are indeed due to this type of disease and the resection of a portion of the rib at the site of the cold abscess is often inadequate, as pointed out by the late J E H Roberts some years ago The posterior intercostal glands are frequently seen to be involved in caseating tuberculosis in chronic upper lobe disease during the course of Semb's extrafascial apicolysis or during an extrapleural upper lobectomy

CONGENITAL ABNORMALITIES OF THE LUNG

Many of these anomalies may imitate an acquired pathological process or be the occasion of complicating disease, and their recognition radiologically or during the course of a thoracic operation is of greater importance than their relative rarity would indicate In the literature of thoracic surgery it has become increasingly apparent that many so-called congenital lesions are in fact acquired and this applies especially to " congenital " cystic disease of the lung On clinical and gross pathological examination many " cystic " lobes suggest an embryological etiology, but a careful survey of the evidence frequently indicates that the specimen under consideration is in fact one of acquired saccular bronchiectasis Obvious congenital abnormalities do, however, present in all parts of the thorax, ranging from tumours, often supposed to be of teratomatous origin but frequently due to faulty budding off from the primitive tracheo-oesophageal tube, through obvious anomalies of pulmonary lobation to partial or complete agenesis which may include one or, quite exceptionally, both lungs The complete absence of both lungs has been noted in an 8 months' premature baby The larynx was developed but the trachea was still in full continuation with the oesophagus and there were no main stem bronchi The failure of bronchial development had presumably occurred at the fourth week of intra-uterine life (Schmidt—quoted by Schneider, P L , 1912)

Defective or excessive lung development

Derived from the entoderm of the foregut and later invested by mesenchyme tissue which soon transcends in importance the entodermal elements, defects of the lung buds may be apparent as early as the fourth week of life Faulty development of the septum between the anterior wall of the foregut and its tracheal bud is responsible for the different varieties of oesophago-tracheal fistula (see Chap 18) From the primitive trachea and larynx the two bronchial stems develop into each pleural cavity The further growth of septa in each bronchial bud leads to the formation of the lobar and segmental bronchi and deficiency or over-division may take place so that agenesis or excessive lobulation may become apparent The primitive entodermal lining remains a well-developed, specialized structure in the bronchi but the epithelial cells of the alveoli rapidly degenerate into flattened discs so that only the thinnest layer remains to permit gaseous interchange between the blood vessels and the alveolar cavities

Agenesis

Complete failure of one lung to develop is compatible with life Usually there is a small bronchus which may be blind or enter into a small mass of lung tissue which is usually

cystic The single lung is often defective in fissures and grows to nearly twice its usual size and bulges into the pleural cavity of the agenetic lung the heart is grossly displaced and in the patient whose radiograph is pictured (Fig 21 5) the apex beat was palpable in the left scapular line posteriorly The development of true emphysema in the single lung is common in later life and dyspnoea becomes apparent usually in the third or fourth decade Occasionally one lung may be hypoplastic an example of this is shown in Fig 1 11



Fig 1 11—Bronchogram of a small hypoplastic left lung

Associated abnormalities were a large patent ductus arteriosus and congenital hemi-vertebrae causing a considerable scoliosis. The patent ductus was divided at the operation the left lung though small, was normal in appearance and there was a considerable amount of fat under the parietal pleura

Supernumerary lungs or lobes

Excessive fissure development is less common than deficient development as will be evident as soon as a number of lobectomies have been done by any one surgeon Perhaps the most frequently noted separation is that of the cardiac lobe of the right lower lobe but it may arise anywhere in the lung fields

Azygos lobe

The development of this lobe as an apparently separate portion of the right upper lobe is not due to faulty bronchial development but depends entirely on an abnormal course

* In several types of lung abnormality and foregut cysts associated aberrant changes include cervical hemi vertebrae and aplasia or absence of a radius. Such aberrations are sometimes seen with thoracic ganglioneuroma These bony changes occur in the area of the neck with which the developing lung and upper limb are connected in early foetal life (Fallon, Gordon and *Lendrum* 1954 Roberts and Weeks, 1957)

of the azygos vein which curves so laterally on its way to join the superior vena cava that it splits off a medial portion of the upper lobe, carrying into the fissure so made a pleural fold which encircles the extrapleurally placed azygos vein This fold is clearly seen on the postero-anterior radiograph (Fig 1 7) The vascular and bronchial supply of the "lobe" is by normal arrangement for the apical segment The azygos lobe may be the site of disease such as tuberculosis and I have once resected it when it was the seat of a chronic lung abscess which radiologically produced the appearance of a mediastinal tumour, not unlike a laterally placed intrathoracic goitre

Accessory lobes or lungs

These are rare but interesting, occurring in the neck, thorax, abdomen, or diaphragm A separate classification into two groups is at once possible those with normal bronchial connections and those without any communication with the bronchial tree



Fig 1·12



Fig 1 13

Fig 1 12 —A tracheal lobe
The probe is in the tracheal orifice which leads to a lobe comprising two separate segments with complete fissure
(Dr H Baar, Children's Hospital, Birmingham)

Fig 1 13 Left upper cystic accessory lobe (*Brit J Surg*)
At autopsy this upper cystic lobe had a separate bronchial and blood supply and was lined by well-developed bronchial epithelium

In the first group may be quoted the instance of the tracheal lobe, and in the second the so-called accessory lower or dissociated lung mass and the discovery of pulmonary masses in the abdomen usually below the left diaphragm , of greatest clinical importance

is the so-called lower accessory lobe Because of this it may be helpful to discuss briefly the position of congenital cystic disease of the lung

Congenital cystic disease It is always tempting to diagnose congenital cystic disease ' from radiological appearances in which circular air spaces are visible or in which lipiodol bronchography reveals spherical oil filled cavities but such an appearance usually represents acquired bronchiectasis If the cysts are isolated from the bronchial tree they are probably congenital in origin an assumption supported by the smoothness of a lining which may show a well-differentiated mucous membrane consisting of ciliated epithelium of bronchial pattern (Fig 1 14) As Gruenfield and Gray (1941) suggest a factual description is preferable to a classification based on assumed congenital etiology if on radiological or pathological examination the cysts are small and multiple a descriptive term such as honeycomb lung should be used the term " air cysts or pneumatoceles being applied to the larger variety

It is indeed difficult to differentiate acquired from congenital bronchiectasis even on the fullest histological examination The presence of inflammatory processes will not serve much in the differentiation for congenital cystic bronchiectasis is often complicated by the addition of pyogenic inflammation

The academic differentiation of congenital from acquired cystic disease is fortunately not of great clinical value for the treatment adopted (resection or conservatism) depends on the symptoms present and the actual state of the patient irrespective of etiological factors Cystic bronchiectasis may be a congenital malformation of the bronchioles or alveoli through inherent lack of elastic tissue or the result of bronchial obstruction (congenital or acquired) or to inflammatory processes The previously held opinion that ' honeycomb appearances *due to congenital disease were commoner in the upper lobes than in the lower* paid too little attention to the possible effects of a healed fibrotic tuberculous process which is commoner in the upper lobe and to the prolonged effect of atelectasis produced by the compressing action of tuberculous glands

Large solitary cysts of the lung

Without labouring over complicated classifications these cysts may be fluid or air containing and it is difficult or impossible to separate the latter from areas of ' emphysema (pneumatocele) a lining of ciliated epithelium is the rule in fluid-containing cysts (see Fig 1 13) They may be classified as upper or lower accessory cysts Both types may represent aberrant budding off of lung tissue which may present in an accessory lobe as in Fig 1 13 this cystic area had a lining of bronchial type epithelium The rare type of fluid containing cyst resembles the bronchiogenic cyst found in the mediastinum (see p 511) These may rupture into a bronchus with the development of a fluid level and infection

Lower accessory lung (dissociated, sequestrated or reduplicated lobe)

Because the abnormal lung tissue may be a large cyst or a mass of ill-developed tissue (Fig 1 14) firmly united to the associated normal lower lobe there has been some confusion in reporting these cases in the literature If both types of condition are considered the condition is of reasonable frequency in thoracic surgery and I have operated on fifteen such patients thirteen had cysts in the left lower chest and two in the right The academic arguments range between two theories (*a*) that the tissue mass represents an area of duplicated or accessory lung tissue derived from an extra lung bud (Baar and d Abreu 1949) or (*b*) that it represents a portion of lung sequestrated and detached from a normally developed lobe

During the early phase of embryonic life the development of the lung may be irregular and accessory masses of lung tissue may arise These ectopic formations sometimes described as " dissociated " lung (Pryce. Sellors and Blair, 1947) usually have a bizarre arterial blood supply from the aorta : in the commonest variety there is cystic formation of the lower lobe and the supplying systemic artery, often a large one, usually arises from the aorta near the diaphragm to ramify in the dissociated lung mass (Fig. 1·15). During the operation of lower lobectomy on a cystic lung the possible presence of such an artery must always



FIG 1 14



FIG 1 15

FIG 1 14—Accessory lower lobe

The probe is in the systemic artery which arose from the abdominal aorta to supply the dissociated mass of lung tissue. Lobectomy specimen.

FIG 1 15—The pulmonary artery supplying the lower lobe and the systemic vessel supplying the " accessory " lobe have been injected with lipiodol

There is no communication between the vascular or bronchial supply of these two sharply demarcated areas of tissue

be in mind The sequestrated lobes or cysts are usually in the area of the posterior segment of the lower lobe There is an established connection in some with diaphragmatic hernia The artery supplying them contains much elastic tissue Abbey Smith (1955) has published an admirable discussion on these aberrancies

Upper accessory lobes

These are found in or attached to the upper lobes (Fig 1 12 1 13) They differ in general from the lower ones in as much as they usually receive their blood supply from a pulmonary artery This was so in an accessory lobe seen in the pericardium which I removed (Fig 13 3) They are even rarer than the lower accessory lobes or sequestrated segments

In both sites infection and rupture into surrounding lung tissue causing bronchiectasis can occur Tuberculous infection has been noted even when there is no bronchial connection with the adjacent lobe ([illegible], 1957) When the cyst type becomes infected the con-

dition may be wrongly regarded as an empyema simple drainage will be followed by persistent drainage until the area usually with the whole or part of the surrounding lobe has been resected The condition may be diagnosed only during the course of lobectomy for bronchiectasis even then it may be overlooked as the supplying vessel may be in the pulmonary ligament which is clamped before division by most surgeons During such a routine procedure the odd nature of the supplying vessel may be overlooked

CONGENITAL COMMUNICATIONS BETWEEN PULMONARY ARTERIES AND VEINS

Abnormal malformations of blood vessels in the lung are difficult to classify but are probably of congenital origin and will be described briefly here rather than under a discussion on hamartomatous formation or as a cause of cyanosis The communications may be described as arterio venous fistula cavernous haemangioma or pulmonary telangiectasis

The pathological basis of an arterio venous shunt in the lung is of less practical importance than the resultant physiological changes that develop Once the condition is suspected the establishment of the diagnosis is not difficult A shunt between the pulmonary artery and the pulmonary vein sufficient to cause dyspnoea, cyanosis and a compensatory polycythaemia is usually due to an angioma of the lung the blood by passing the normal capillary bed and not being oxygenated This may be associated with telangiectasis elsewhere especially in the lip mouth and tongue when the condition is often familial (Osler s disease) The condition may involve both lungs (50 per cent of the reported cases) (Janes 1944) and quite rarely undergoes malignant transformation even producing metastases Angioma of the lung may be of sufficiently small size to be quite unassociated with any circulatory disturbances Frequently a dilated tortuous pulmonary artery enters a large sac from which the blood passes on to the vein the intima of the arterial vessels is normal but there is very little muscle detectable in their walls The pulmonary vein histology is normal, the lesion clearly being a varicosity of the arteries exclusively as is the case in cerebral angiomata The recognition of the condition is specially important because surgical cure is often simple The first lung resection in this condition was carried out by Shenstone in 1940

Symptoms and signs There may be none if the shunt is small Autopsy records indicate that angiomata may have been present in life without occasioning any symptoms and it is possible that in some of these patients the malformations had involved the bronchial vessel systems so that no communication existed between the pulmonary artery and vein and therefore no appreciable shunt existed Cyanosis dyspnoea and haemoptysis (sometimes fatal) may be combined the cyanosis may have dated from early life but this is not invariable (One of our patients a man of 27 suddenly developed symptoms of dyspnoea and cyanosis seven years before admission for surgical treatment) Telangiectasis may appear quite suddenly on the skin and mucous membranes and the same process is at least possible in the lungs but once developed it is progressive Cough is present in some patients and its association with clubbed fingers and toes (an invariable accompaniment of lung arterio venous fistula associated with symptoms) may lead to the patient s reference to a chest clinic as suffering from bronchiectasis The anoxaemia present may cause cerebral symptoms and nose bleeding has been noted.

Polycythaemia is marked the heart does not enlarge as in arterio venous aneurysm involving the greater systemic circulation and the cardiac output is not increased since the

blood pressure is not raised as it is in the systemic type of fistula In more than half the patients a systolic murmur is audible over the affected lung area and if the lesion is placed superficially a thrill may be felt, the murmur becomes louder on inspiration

Radiological studies of the chest reveal an area or areas of increased density and the study of these is helped by tomography and by angiocardiography The shadows enlarge on inspiration The opacities are usually irregular and the vessels leading to them are dilated, enlarged and tortuous The discovery of lung opacities in a patient with clubbed fingers and toes, cyanosis and polycythaemia should at once suggest the possibility of an arterio-venous fistula, in the absence of evidence of congenital cardiac disease Maier (1948) has described an unusual complication of bacterial infection Cardiac catheterization and physiological studies not only confirm the diagnosis but enable an estimate of the size of the shunt to be made The history, physical signs and laboratory studies are well exemplified by the following case history

F E, a man of 25, was referred to Dr Brian Taylor for persistent cough, cyanosis and breathlessness which had developed progressively over a period of six years, pneumonia had been diagnosed at the age of 11 He was obviously cyanosed and the fingers and toes were clubbed, a few rales were present at both bases, but the main physical sign was a systolic bruit over the base of the left lung, the diagnosis was that of arterio-venous fistula and a lipiodol bronchogram excluded any associated bronchiectasis There was no telangiectasis of the lips or mouth or of any cutaneous surface The blood picture revealed a polycythaemia (6,500,000) Tomographs and angiocardiographic studies demonstrated dilated vascular channels in the left lower lobe The electrocardiograph showed a left ventricular preponderance

Cardiac catheterization and arterial blood estimations were carried out (Dr Paul Davison) The results were as follows

	Pressure (mm Hg)	O_2 Content, vol per cent	Percentage O_2 saturation
Main pulmonary artery	20/7	7 86	47 5
Mid-right auricle	—	8 14	49 2
Right femoral artery breathing air	—	11 94	72 2
Right femoral artery inhaling pure oxygen	—	13 50	81 6
Oxygen capacity of blood	—	16 54	100 0
Normal pulmonary veins (calculated 95% saturated)	—	15 72	95 0

Metabolic rate = 335 c c oxygen per minute

The pulmonary artery pressure was normal the low oxygen saturation of the arterial blood (72 per cent) not converted by oxygen inhalation (82 per cent) confirmed the presence of a large intrapulmonary shunt Assuming that the mixed venous blood passing through normal lung becomes 95 per cent saturated with oxygen and that the blood going through the arterio-venous aneurysm receives no oxygen the size of the shunt was calculated as follows

(1) Arterio-venous oxygen difference
 Femoral artery — mixed venous blood $= 11\ 94 - 7\ 86 = 4\ 08$
 Normal pulmonary venous blood — mixed venous blood $= 15\ 72 - 7\ 86 = 7\ 86$

(2) Therefore on the Fick Principle

(*a*) Total pulmonary blood flow $= \frac{335}{40\ 8} = 8\ 21$ litres/minute

(*b*) Blood flow through normal lung capillary bed $= \frac{335}{78\ 6} = 4\ 26$ litres/minute

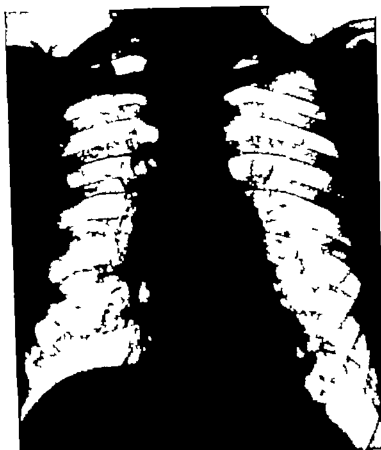
(3) Therefore the size of the pulmonary shunt $= 8\ 21 - 4\ 26 = 3\ 95$ litres/minute

or $\frac{3{\cdot}95}{8\ 21} \times 100 = 48$ per cent

The shunt was taking about half the blood flow through the lesser circulation

A left lower lobectomy was therefore done The cyanosis disappeared immediately the pulmonary artery to the lobe had been ligated, the patient recovered rapidly and all symptoms disappeared Three weeks after operation the arterial oxygen saturation was normal

As expected cardiac catheterization in the case described showed the cardiac output to be normal and no rise in the pressure in the chambers because of the satisfactory way in which the pulmonary circulation accommodates a large extra flow of blood great enough in the case above to produce approximately a 50 per cent shunt





(a) (b)

Fig 1 16

(a) Arterio venous fistula of lung

Radiograph howing abnormal shadow in left lower lobe in a man with cyanosis.

(b) Radiograph of left lower lobe excised for arterio-venous fistula

The pulmonary artery supplying the lobe ha been filled with lipiodol, which is entering int a mass of dilated vessels which drain off by large channels int the inferior pulmonary vein.

Differential diagnosis Cyanosis and dyspnoea associated with polycythaemia is more often due to congenital heart disease than to arterio-venous fistula of the lung In congenital heart disease the findings of cardiac signs by auscultation and radiography will at once establish the source of the polycythaemia confusion with polycythaemia vera is avoided if splenic enlargement is detected and is easily excluded if a murmur is heard in the chest and if tomography and angiocardiography is undertaken in the presence of doubtful lung opacities

Surgical treatment The only hope of cure is by excision of the angioma and this is indicated if symptoms are at all severe this may be done by segmental resection Janes (1944) first recorded multiple resections two angiomata being removed from the right lung followed at a later stage by resection of another from the left side Lobectomy or pneumonectomy dependent on the location and extent of the blood vessel abnormalities may be necessary If the condition is bilateral the extent of the resection must be as conservative

as possible for this reason angiocardiography should be performed before operation, as this not only outlines the extent of the condition but may show up angiomatous areas unrevealed by straight radiography Before operation is undertaken the surgeon must be quite certain that no area of shunt is undetected

Because of the risk of phlebo-thrombosis in any patient with polycythaemia an adequate fluid balance must be maintained during and after operation An intravenous saline drip is set up during the operation, blood not being given unless severe bleeding takes place

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CHAPTER 2

LUNG FUNCTION

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This chapter is a brief review of those aspects of cardio respiratory function whicl of particular importance in clinical medicine and surgery The great advances in tho surgery in recent years have further emphasized our relative ignorance of this fundam subject Nevertheless the methods now available if sufficiently used and correlated clinical findings and surgical experience will yield most valuable information particu in helping to assess the safety of various surgical procedures It would be invaluable if t responsible for the training and selection of chest physicians and surgeons insisted on working with cardio-respiratory units at a relatively early stage of their careers In this they would develop an informed curiosity concerning physiological aspects of their su and an ability to be more critical of the real value of various tests of respiratory func

The three important aspects of lung function ventilation pulmonary circulation the oxygenation of blood flowing through the lungs, are considered under separate head A further section deals briefly with differential lung studies or bronchospirometry I attempt to clarify this account the discussion of methods is under separate headin the end of the chapter

Ventilation of lung

Shortness of breath is one of the most common symptoms in patients with respir disease In recent years there has been increasing evidence that this sensation is no to any subtle biochemical or gaseous changes in the body or central nervous system I no more than ventilatory discomfort This discomfort is caused by the lung ventil during any particular activity being too great for the ventilatory capacity present simple concept of the lungs as a pair of bellows and consideration of their capaci move air in and out of the chest in relation to the demands made upon them, has bee of the most important advances in the study of lung function.

Shortness of breath or ventilatory discomfort can be caused either by a decre the ventilatory capacity or by an undue increase in the lung ventilation or by a combir of the two Let us first consider how the ventilatory capacity can be assessed and this can be related to the ventilatory demands under different conditions

Hermannsen (1933) first pointed out that a most useful assessment of the efficier the bellows action is obtained if the volumes of gas shifted by the lungs during ma voluntary hyperventilation over a standard period of time are measured The volu gas breathed during this hyperventilation is stated in litres per minute and is kno the maximum breathing capacity This is a valuable measurement as it is affect many important factors such as the patency of the air ways the efficiency of the respi movements and the elasticity and rebound of the lung tissue and movable compone the chest wall. In the average healthy young adult the maximum breathing capac

of the order of 160 litres per minute In more athletic persons values over 200 litres per minute have been recorded These remarkable amounts of air are shifted by the subject while at rest and are in no way related to any physiological demand such as exercise Ventilatory volumes of this order are never reached during the most violent exertion, even when a normal person exercises to utter exhaustion and agonizing shortness of breath It has been shown that, if the volume ventilated during exertion is more than a third of the maximum breathing capacity, then ventilatory discomfort will be experienced This discomfort, or dyspnoea, increases as the ventilatory volumes increase and when half the maximum breathing capacity is reached, then even a normal person will be very uncomfortable and short of breath Thus, if an attempt is to be made to quantitate the degree of dyspnoea of a person under given conditions, the maximum breathing capacity must first be measured and then the actual volumes ventilated related to that figure It cannot be over-emphasized that although the maximum breathing capacity is a most useful empirical measure of the ventilatory function or the bellows action of the lungs, it does not represent the maximum amount of air that can be ventilated in response to normal physiological stimuli such as exercise The true ventilatory capacity, defined as those volumes which can be ventilated during exercise without undue distress, is slightly less than half the maximum breathing capacity

What are the factors that reduce the ventilatory capacity ? Any form of tracheobronchial or bronchiolar obstruction will interfere with the free passage of air in and out of the lungs Bronchospasm will cause such obstruction and greatly reduce the ventilatory capacity In both the bronchitic and asthmatic subject, congestion and oedema of the bronchial mucosa and secretion contribute to this obstruction If bronchial obstruction continues over a long period then pulmonary emphysema will develop, the lung substance itself becoming distended and inelastic This loss of lung elasticity, which is also associated with an expanded and relatively fixed thoracic cage, will also cause considerable reduction of the ventilatory capacity, interfering particularly with the normal expiration which depends more upon the natural rebound of the lung and chest than upon active muscular effort In most cases of emphysema there is some element of bronchospasm and these two factors combine to lower ventilatory efficiency Attempts are made to assess the obstructive factor by determining the increase in the maximum breathing capacity after adrenaline injection or inhalation, but this increase is never of the same order as that after a natural remission of bronchospasm

The ventilatory capacity (as measured by the maximum breathing capacity) is considerably affected even in relatively mild emphysema and, although there is much more work to be done on the normal values in persons of different ages and body size, there is usually no difficulty in recognizing that there is a significant reduction of the ventilatory capacity Care must be taken in relating these figures to published findings in normal persons If possible, the maximum breathing capacity of normal subjects of different ages, sex and sizes should be determined with the particular apparatus used

The main disability in pulmonary emphysema is the impairment of the ventilatory capacity It is the primary cause of the shortness of breath which is the conspicuous symptom of the disease

In patients with pulmonary fibrosis (i e pneumokoniosis) but without emphysema, there is rarely any marked impairment of the ventilatory capacity This is because there is little, if any, bronchospasm and the lungs are not overstretched and are still able, by virtue of their elasticity, to force the air rapidly out of the chest when inspiration ceases However, if bronchitis, bronchospasm, emphysema, or marked lung deformity from massive

scarring occur then the ventilatory capacity will fall considerably A number of patients with pulmonary fibrosis show abnormally increased ventilation on exertion, and this will contribute to their shortness of breath.

In the last few years attempts have been made to measure the actual work done in moving air in and out of the lungs The pressure changes in the pleural space are measured by an electromanometer attached to an intra-oesophageal catheter ending in a balloon The volumes of air breathed are measured by a pneumotachygraph (Lilly) or a very low inertia and resistance spirometer (Bernstein) The use of such a spirometer allows the immediate photographic recording of the relationship of pressure to volume during a breath (Arnott, 1954)

The work carried out in breathing can be divided into the viscous work entailed in moving gas through the airways into the alveoli and the elastic work in expanding the lungs It is obvious that viscous work will be increased if the airways are in any way obstructed (bronchitis bronchospasm) Similarly elastic work will be increased if the lungs are more rigid than normal (lung fibrosis, pulmonary congestion) There are other factors involved such as tissue viscance gas elastance and the work of moving the chest wall as well as the lungs

Despite these measurements of respiratory work it has not yet been possible to relate precisely the amount of work done or the negativity of intra pleural pressure to the sensation of dyspnoea However these developments are most valuable as they give greater insight into causes of ventilatory insufficiency An example of this is the recent realization that in severe emphysema the loss of lung elasticity and negativity of intrapleural pressure when inspiration has ceased may cause smaller airways to collapse if a positive pressure is generated in lung around them in order to overcome viscous resistance on expiration Thus so-called bronchospasm in many patients with emphysema may be mechanical more than bronchomotor

References (Otis 1954 Christie 1953) are given for those who wish to study developments in this field

Ventilatory considerations before lung resection

Providing resection of lung does not cause intolerable right heart embarrassment or fatal anoxaemia both rare events the limiting factor as regards activity after operation is the ventilatory capacity If this is greatly impaired then the patient will be unduly short of breath on exertion High ventilatory volumes on moderate exertion will also contribute to this dyspnoea

Before operation the maximum breathing capacity and the volumes ventilated while walking at moderate speed can be easily determined. It is now established that the volume of air ventilated during a fixed degree of activity is rarely significantly altered by any resection or collapse procedures Thus if the effect of the operation on the ventilatory capacity can be foretold and it is known that it will remain more than two and a half times the walking ventilation then the patient will be able to walk at reasonable speed without undue discomfort Unfortunately the effect of various procedures on ventilatory capacity can only be predicted by intelligent guessing guided by previous experience Warring (1949) screens the patient and watches rib and diaphragmatic movement and the lighting up and emptying of the lung fields on each side during quiet and forced respiration He has developed a remarkable ability to foretell the post-operative ventilatory capacity using a somewhat empirical system of *marking* the rib and diaphragm movement on each side The method is of value and gives those who employ it a considerable insight into the problem

of ventilatory sufficiency Warring also follows the maximum breathing capacity during various stages of a "doubtful" pneumothorax or thoracoplasty and is able to assess with reasonable accuracy the risk of making the patient a "ventilatory cripple" at each stage

All authorities are now agreed that a maximum breathing capacity of 35 litres per minute or less renders any operative interference out of the question

There is the occasional problem of a patient with an apparently operable carcinoma of the lung and considerable emphysema If the patient had little respiratory disability before this illness then it is unlikely that he has true emphysema Clinical and radiological assessment of this disease can be very misleading, but the demonstration of a relatively unimpaired maximum breathing capacity will often reassure the surgeon If, however, the patient suffered from shortness of breath for some time before the development of the growth and the maximum breathing capacity is low he may well be a ventilatory cripple after resection, and the decision to operate must rest with the patient and his medical adviser Usually resection is carried out and, although the ventilatory capacity may be so reduced that the patient is unable to walk in comfort, there have been gratifying and surprising results At this age life is sweet, even in an armchair

Before passing on to the consideration of lung volumes, mention should be made of the factors causing excessive ventilation on exercise, these are ill-understood If there are considerable areas of lung which are still ventilated, but have impaired circulation, then this ventilation is wasted, so far as gas exchange is concerned, and the added burden of ventilating this relatively functionless lung will cause a proportionate increase of the total ventilation There is good evidence that this so-called "dead space effect" can be considerable in lung disease, especially in emphysema (Donald, 1952)

If, owing to the poor correlation of ventilation and perfusion in the lungs, or reduction or abnormality of the effective blood-gas interface where oxygen transfer can take place, there is considerable arterial anoxaemia on exertion, then there will be a marked increase of ventilation Anoxaemia, although only a mild respiratory stimulus at rest, causes a great increase of pulmonary ventilation if associated with exercise Thus marked cyanosis, due to arterial blood desaturation on exercise, is important, in this respect, as it causes large ventilatory volumes which may give rise to considerable discomfort, even if the ventilatory capacity is not greatly reduced

Hyperventilation due to anoxaemia is particularly important in those patients who maintain a good ventilatory capacity despite abrupt arterial desaturation on exercise (alveolar wall infiltration causing diffusion disturbances and congenital heart disease provide examples) It is not so important in those diseases where the ventilatory capacity is greatly impaired (emphysema)

This powerful anoxaemic hyperventilation on exercise will wash carbon dioxide out of the body and the buffers (alkali reserve) will fall accordingly This, again, will render the respiratory centre more sensitive to carbon dioxide and hydrogen ions and tend to perpetuate high respiratory volumes, even at rest In the later stages of emphysema there is temporary retention of carbon dioxide due to ventilatory insufficiency, each time the patient exercises In such cases the body buffers will increase and when the body and lung carbon dioxide become permanently raised the ventilatory volumes fall owing to relative insensitivity of the respiratory centre to carbon dioxide stimulation It is, of course, not a true insensitivity but an increased chemical protection of the respiratory centre

Finally, many authorities postulate that increased ventilation may be reflex and due to the pathological processes in the lungs increasing the sensitivity of the Hering Breuer reflex There is, as yet, no convincing proof of this

This brief account mainly emphasizes our ignorance of this important aspect of lung

function but it is fortunate that the ventilatory demands can be directly measured in any particular case during a fixed degree of activity Gray's valuable monograph on the physiological regulation of pulmonary ventilation is to be recommended (1950)

Lung volumes

The lung volumes are the boundaries within which ventilation takes place It is now generally agreed that too much emphasis has been placed on this aspect of lung function Although these measurements are useful in a full and detailed study of any patient they are of less value when considered alone and it is most unwise to make general conclusions concerning respiratory function from their study alone

Fig 2 1 shows the lung volumes using Christie's terminology (1932) which has been in general use for some time in Britain Fig 2 2 shows the new terminology agreed upon by a large number of workers in the field (Pappenheimer, 1950) In the author's opinion this terminology is a considerable improvement as the terms are more self-explanatory and the use of the word air to describe a volume is avoided.

The maximum volume the lungs can attain is termed the *total capacity* the minimal volume the *residual volume* The difference between these two volumes which represents the maximum volume of air that can be expired after a maximum inspiration is by Hutchinson's definition the *vital capacity* The volume of air in the lungs at the end of a quiet expiration is the *functional residual capacity* As most spirometric studies are from respiratory charts this base line' of quiet respiration is known loosely as the resting respiratory level a convenient but unscientific term

The vital capacity is easily measured in any closed circuit and usually a tracing is taken The inspiratory capacity and the expiratory reserve volume are the two components of the vital capacity which are measured from the resting respiratory level As these volumes are measured outside the body they must be converted to body temperature (saturated with water vapour) It is now common experience that the vital capacity and its subdivisions although frequently decreased in respiratory disease are in any individual case a most unreliable index of general respiratory or ventilatory function. Although a study of the lung volumes gives an accurate assessment of the size and range of the lung bellows it is a static volume measurement and gives no indication of the efficiency and speed of ventilatory movements within this range

It was hoped that the determination of the residual volume and total capacity would add greatly to the value of lung volume measurements The volume of gas in the lungs can be determined by a number of indirect methods The one most often used in this country depends upon measuring the degree of dilution of a known volume of an inert physiologically inactive gas such as helium in the lungs The other common method, which is extensively used in America depends upon the measurement of the change of the percentage of alveolar nitrogen after seven minutes oxygen breathing The expired gas is collected and the determination of the absolute amount of nitrogen washed out by the oxygen allows the volume of gas in the lungs to be calculated.

Both these methods give satisfactory results The determination is carried out during quiet respiration the patient being connected to the circuit at the end of a normal expiration Thus the functional residual capacity is obtained and the residual volume determined by subtracting the expiratory reserve volume which is measured before or after the experiment

The residual volume can be expressed in absolute terms or as a percentage of the total capacity This volume is normally 20–25 per cent of the total capacity but up to a third

(33 per cent) of total capacity is now considered within normal limits However, it must be emphasized that it is not unusual to find middle-aged persons with no lung disease or dyspnoea, with residual volumes which are 40–50 per cent of a normal total capacity

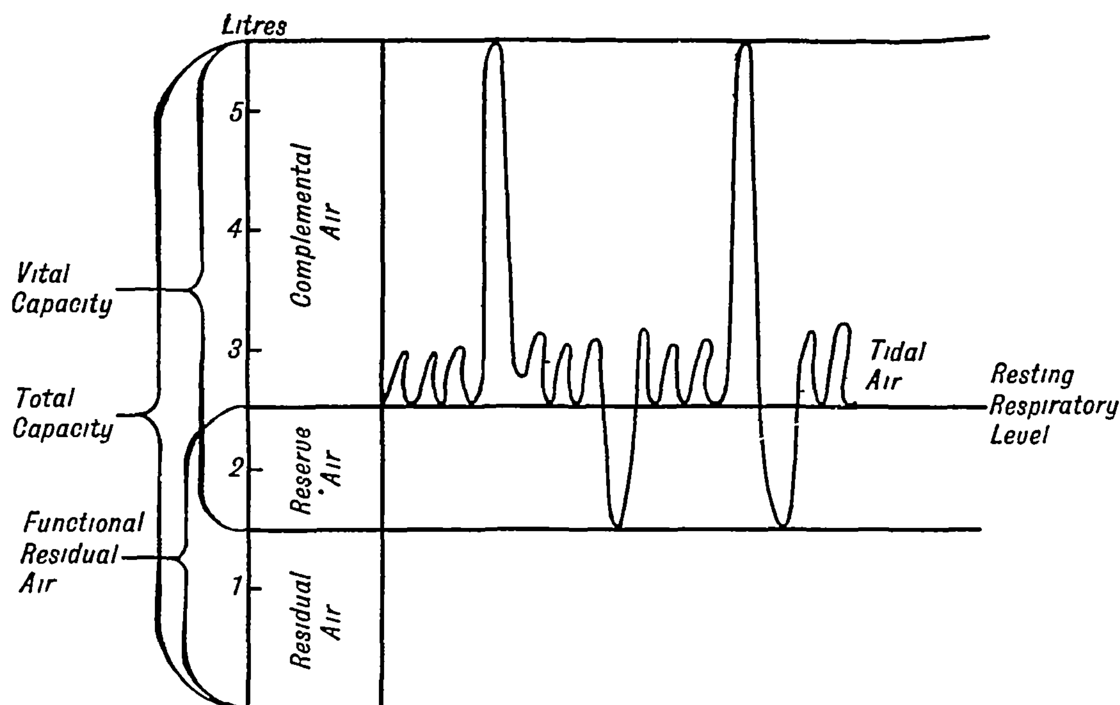


FIG 2 1—The lung and its subdivisions (R V Christie, 1932)

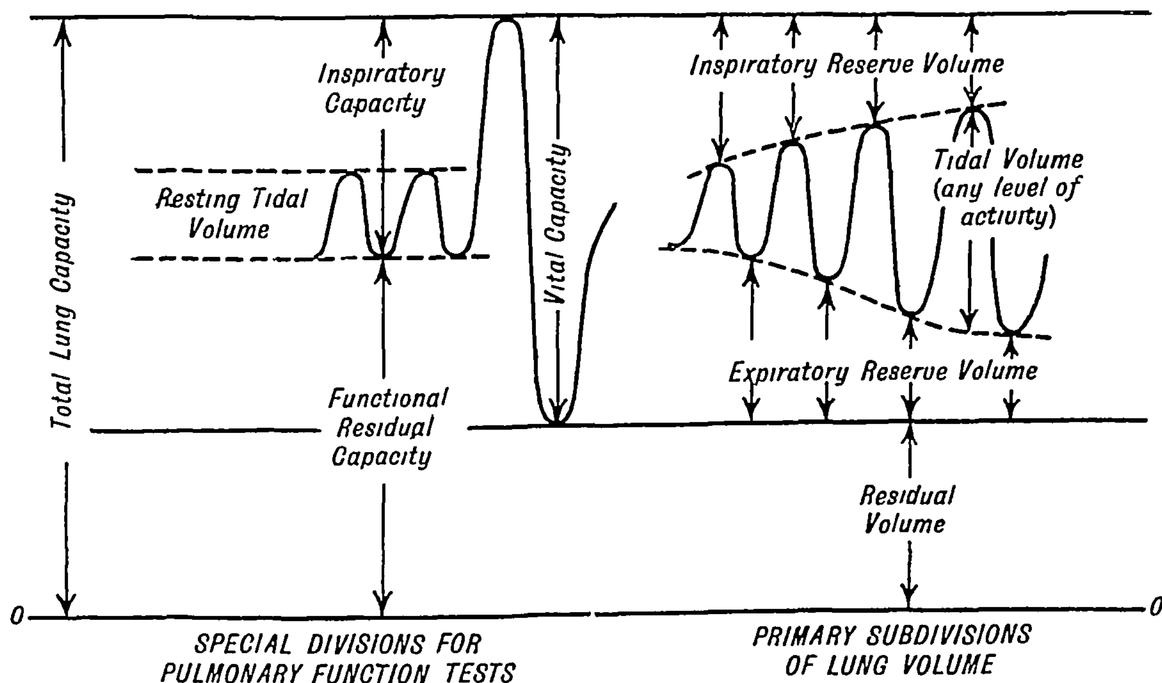


FIG 2 2—Subdivisions of the lung volume (J R. Pappenheimer, 1950)

Although in general the residual volume is considerably increased in pulmonary emphysema, this increase is not directly proportional to the degree of disability. Very moderate cases of emphysema, who are but little handicapped, have residual volumes over 50 per cent of the total capacity, and others who are respiratory cripples with considerable cyanosis have

but little increase of the residual volume Furthermore with few exceptions the total capacity in emphysema is within the normal range Thus as the total capacity is the sum of the residual volume and the vital capacity it is to be expected that assessing the respiratory disability by the increase of residual volume will be as disappointing as assessing it by the reduction of the vital capacity

In most cases of lung fibrosis or generalized pulmonary infiltration (Boeck s sarcoid neoplastic infiltration granulomata) the total lung capacity is reduced and its various subdivisions are proportionately decreased In some patients however the residual volume will be normal in absolute terms and thus more than 33 per cent of the total capacity It is at present impossible to diagnose superadded emphysema in such cases by lung volume studies alone

When there is unilateral fibrosis or collapse or different types of damage on the two sides the accurate interpretation of lung volume data by external spirometry is impossible The study of lung volume on each side by bronchospirometry a tedious procedure is an advance but even this method is full of difficulties Lung volume changes may be due to actual emphysema or fibrosis or to mechanical events in the chest such as mediastinal shift collapse pleural changes or diaphragmatic paralysis

Finally lung volume data are useful when considering every aspect of a difficult respiratory problem but the time and trouble taken to determine the residual volume is only justifiable in large units which are well equipped with both apparatus and personnel

Lung circulation

The pulmonary circulation is a low pressure system. The short distensible and capacious pulmonary arteries arterioles and pre-capillaries and the enormous network of large pulmonary capillaries surrounded by air allow the whole cardiac output to flow through the pulmonary vascular bed with a pressure head of only one-sixth of that in the systemic circulation Even marked exertion with a fourfold increase of cardiac output will cause little or no rise in the pulmonary artery pressure (Riley 1948 Dexter 1951) The only factor known to cause a significant rise of pulmonary artery pressure in normal subjects is the breathing of low tensions of oxygen (Motley 1947) The determination of pulmonary artery pressures involves cardiac catheterization (see Chapter 15) and on the whole this is only necessary when the natural history of pulmonary hypertension in various lung diseases is being studied

In emphysema the pulmonary artery pressure at rest is only slightly raised even in patients with long histories and severe lung damage This is not altogether surprising as the clinician has long known that the majority of emphysematous patients with gross ventilatory insufficiency have small vertical hearts When these subjects exercise there may be a considerable rise of the pressure in the pulmonary artery It is possible that the right ventricle of these patients is protected by their inability to carry out any sustained exertion owing to extreme ventilatory discomfort

Those patients with pulmonary emphysema and a large heart due to right ventricular hypertrophy are usually first seen when in acute congestive failure precipitated by a severe anoxic episode such as bronchopneumonia This would suggest that their ventilatory disability has not been marked and that they have been able to carry out considerable exertion with associated pulmonary hypertension over long periods In time this will inevitably cause right ventricular hypertrophy Any added burden such as severe anoxia due to pneumonia or severe bronchitis with respiratory obstruction may precipitate right heart failure

The natural history of pulmonary hypertension and right-sided heart failure in lung fibrosis, severe bronchiectasis or fibrocaseous tuberculosis is still not yet adequately studied

Cournand (1949) has shown that if a normal lung remains after pneumonectomy, and it is not unduly damaged or distended by scoliosis or by mediastinal shift, then this single lung can accept the cardiac output in all degrees of exertion encountered in a normal existence without any rise of pulmonary artery pressure Although some rise of pressure has been shown on extreme exertion, some of these patients have lived normally, and even indulged in tennis and swimming, for up to ten years with no evidence of right ventricular hypertrophy

Occasionally a lung resection will cause unexpected and irreversible right-sided heart failure With the rapid development of chest surgery there is an urgent need for greater knowledge of pulmonary haemodynamics in various diseases and after resection In long-standing or bilateral lung disease where resection is visualized, great care should be taken not only to consider the ventilatory capacity but also the state of the pulmonary circulation and the right heart A loud pulmonary second sound should be looked for and the right ventricle examined clinically, by screening, and electrocardiography (Myers, 1948)

If there is any doubt concerning this aspect then cardiac catheterization, if available, should be carried out At present there is not enough data to allow a definite opinion concerning the safety of resection to be given in each case, but these important ancillary investigations should be used more frequently and, with increasing experience, they will become more and more valuable

Hansen and Carlens (1950) are developing a method whereby the pulmonary artery of the lung to be resected is occluded by a balloon on a cardiac catheter, and any undue rise of the pressure in the main stem of the pulmonary artery during moderate exercise on an ergometer can then be demonstrated Other workers carry out continuous observation of the pulmonary artery pressure during any " dubious operation " by means of an intra-cardiac catheter (Mendelsohn, 1950) The pulmonary artery of the lung to be resected is then gently clamped and the pressure in the main stem, which should return to normal in a few minutes, is noted These methods are not yet fully developed, but they show that this problem can be, and no doubt will be, solved The first and most important step is to be aware of the problem

Finally, it is most important to avoid anoxia post-operatively, particularly in those patients who may be in danger of right heart failure Traumatic and infective oedema, collapse, pleural effusion and haemorrhage, and bronchial irritation and blockage all combine to prevent adequate ventilation and oxygenation of blood passing through the lungs Further, the low oxygen tensions in many parts of the lung will almost certainly cause pulmonary vasoconstriction and increased work for the right heart which is already handicapped by arterial anoxaemia These patients should be maintained in an oxygen tent until the clinician is satisfied that alveolar ventilation is restored, as evidenced by the disappearance of cyanosis If there is any doubt, arterial puncture should be performed and the arterial blood oxygenation precisely determined

In the last edition it was stated that carbon dioxide narcosis was unlikely in patients receiving oxygen therapy after thoracic operations, as patients with gross and chronic emphysema or respiratory insufficiency are rarely operated upon However, experience has shown this to be incorrect Patients with fairly good lung function may suffer from such severe temporary anoxia and carbon dioxide retention at some time during or after operation that they pass into very severe central respiratory depression and spontaneous

respiration may be absent or quite inadequate with or without oxygen These patients will therefore have very high levels of carbon dioxide in the body Assisted respiration with oxygen either through a mask or a temporary tracheotomy may be life-saving in reducing carbon dioxide levels to normal and promoting spontaneous respiration There is little doubt that mechanical respirators will be an essential part of the equipment of all thoracic units in the future

Blood oxygenation

Cyanosis is caused by an undue amount of reduced haemoglobin in the peripheral circulation It is most noticeable in the regions where there is a generous capillary bed (nose cheeks ears hands feet) or in the mucous membranes There are two main causes of cyanosis If the blood passing up the aorta is inadequately oxygenated then the cyanosis resulting from this is termed central cyanosis This state of affairs is found in congenital heart disease where unchanged mixed venous blood is shunted across into the left heart without passing through the lungs and in various lung diseases where although the blood flows through the lungs it is still inadequately oxygenated

The second main cause of cyanosis is a low cardiac output due to impaired cardiac efficiency There is a considerable peripheral and cutaneous vasoconstriction which no doubt conserves heat and maintains an adequate blood pressure despite the decreased inflow into the arterial system The maintenance of an adequate arterial blood pressure is essential for the blood supply of the brain and other vital organs and if this compensatory vasoconstriction fails (peripheral failure) then the patient is in grave danger The thoracic surgeon who is now operating more and more on patients with low systemic blood flow (mitral stenosis and many congenital heart diseases) must be constantly aware of this hazard and every detail, from room temperature to the gentle handling and retraction of tissues must be considered with care to avoid the not infrequent situation of a successful operation followed by irreversible peripheral failure

To return to the consideration of patients with peripheral cyanosis if an arterial puncture is carried out then it can be shown that the blood from the left heart is well oxygenated A number of patients in low output heart failure may show slight desaturation of the arterial blood It is not yet known whether this is due to mild concomitant emphysema, gaseous alkalosis caused by the hyperventilation of heart failure with washing out of carbon dioxide or to actual interference with the transfer of oxygen in the lungs due to the chronic congestion.

Clinical assessment of the degree of arterial desaturation is most unreliable even when the cyanosis is purely central in origin Different lighting skin pigmentation and circulation and many other factors will frequently deceive even the shrewdest eye If arterial desaturation is suspected then an arterial puncture should be done and precise values obtained The use of oximeters or the analysis of capillary blood are not satisfactory and resorted to by those who are under the false impression that arterial puncture is painful and difficult

Let us now briefly consider the causes of central cyanosis due to the inadequate oxygenation of blood in the lungs In pulmonary emphysema the main cause of arterial desaturation at rest is the inefficient distribution of the inhaled air and of the mixed venous blood from the right heart Many alveoli are still perfused with blood but receive practically no additional fresh inspired air during normal respiration. Thus little oxygen can be added to the blood passing through them and the lung tissue is to all intents and purposes functionless The mixed venous blood passes through such lung tissue almost *unchanged*

with the same effect as a right to left intracardiac shunt ("venous admixture" effect) Similarly, certain parts of the emphysematous lung may still be adequately ventilated but receive little venous blood owing to the destruction and limitation of the pulmonary vascular bed in this disease This "dead space" effect will also render areas of lung quite functionless It is obvious that this cannot cause arterial desaturation directly as no blood flows through such lung tissue

However, in very severe emphysema, the combined effect of functionless lung, due to impaired alveolar ventilation and to impaired alveolar circulation, will leave such a small part of lung where blood and gas are efficiently brought together, that when the patient exercises the limited blood–gas interface does not allow the adequate transfer of oxygen to balance the increased oxygen uptake, and dramatic arterial desaturation (anoxaemia) will result Such patients are in a very similar position to a person who has suffered excessive lung resection, as only a small part of the lung tissue is capable of maintaining efficient gas transfer between blood and alveolar gas

The ability to transfer oxygen from alveolar gas to blood is described, in general terms, as the diffusing capacity When a normal subject exercises the oxygen transfer is increased by a number of mechanisms Increased ventilation raises the alveolar oxygen pressure and the removal of greater quantities of oxygen from the circulating blood will also add to the size of the diffusion gradient and resultant oxygen transfer in the lungs It is also probable that the pulmonary capillary bed expands considerably with increase in cardiac output and that the diffusing surface is further increased

If the arterial blood percentage saturation is studied in emphysematous subjects at rest, the desaturation found is never of the extreme order seen in many cases of congenital heart disease with right to left shunt Figures below 85 per cent are unusual and even this figure is roughly equivalent to a 40 per cent shunt of unchanged blood This, no doubt, is the main reason why marked polycythaemia, which would also contribute to cyanosis, is unusual in pulmonary emphysema The arterial desaturation at rest is due to "venous admixture" effect from underventilated alveoli and not to limitation of the diffusing capacity

It is of interest that polycythaemia is most marked in those emphysematous patients with large hearts and right ventricular hypertrophy who are usually first seen in failure owing to an acute anoxic episode such as severe bronchitis, bronchopneumonia or status asthmaticus Again it is possible, as already suggested, that these patients may have had sufficient ventilatory capacity to allow considerable exertion and resultant anoxaemia over long enough periods to stimulate excessive red cell production

Generalized lung fibrosis does not usually cause any marked anoxaemia, even on considerable exertion, unless emphysema is present as well Recently some exceptions to this have been reported but it is not yet known whether this is due to alveolar underventilation or to the reduction of effective lung tissue

There is another group of patients with generalized pathological infiltration of the lung tissue (some cases of Boeck's sarcoid, beryllium granuloma, neoplastic and granulomatous infiltrations) who have pathological changes in the alveolar wall which interfere with the normal diffusion of oxygen These patients often have efficient distribution of inspired air and mixed venous blood to all alveoli, and the ventilatory capacity is little impaired At rest most of these patients have normal or near-normal saturation of the arterial blood. However, they have no reserve diffusing capacity, and even moderate exertion will cause extreme arterial desaturation despite an excellent ventilatory capacity Diseases destroying large areas of lung (cystic disease, fibrocaseous cavitating tuberculosis, extensive

bronchiectasis) give a similar picture due to the very limited amount of functioning lung and the resultant decrease in diffusing capacity

Speaking in general terms tuberculosis excluding bronchial stenosis and pleural fibrosis reduces both the circulation and ventilation of the diseased areas to a very similar degree and such patients may have considerable lesions without any significant arterial desaturation If there is definite cyanosis at rest then the disease is very extensive indeed or there has been a recent event such as a sudden spread interfering with alveolar ventilation over a considerable area of lung

Finally what help will arterial blood studies be in the selection and rejection of cases for lung resection ? This cannot be answered satisfactorily until more chest units carry out these studies before and after resection Yet a number of important principles can be laid down Firstly the arterial saturation at rest is mainly a function of the efficiency of gas distribution, whereas on exercise it is mainly a measure of the quantity of functioning lung and its diffusing capacity Distribution disturbances i e alveolar underventilation are rarely severe enough to threaten life except in acute respiratory infection or status asthmaticus in emphysematous patients The greatest danger from the point of view of blood oxygenation is to leave a patient with a quite inadequate diffusing capacity For example if an emphysematous patient with a peripheral bronchial carcinoma and an adequate ventilatory reserve has some arterial desaturation at rest but this remains unaltered on moderately severe exercise then this would indicate that although there is considerable venous admixture due to poorly ventilated alveoli there is still a large amount of functioning lung with reasonable diffusing capacity Such a finding would weigh heavily in favour of the safety of resection

Bronchospirometry

It has long been the ambition of respiratory physiologists to be able to study the function of separate portions of the lungs Jacobaeus (1933) first showed that it was possible by means of a double-channelled bronchoscope with balloons to obtain satisfactory respiratory tracings showing the tidal air ventilatory volumes and oxygen uptake of each lung Gebauer (1939) and Zavod (1940) designed, independently soft rubber catheters which rendered the procedure less unpleasant and traumatizing Further the resistance was less and the maximum respiratory excursion was closer to the vital capacity than when employing a bronchoscope

The resistance was, however still excessive and Norris (1940) therefore evolved a single lumen catheter with a mask One lung breathes through the catheter and the other round it into the mask. Although this reduced respiratory resistance considerably it was not altogether satisfactory particularly as the resistance and dead space were different for each lung All these catheters had to be inserted under fluoroscopic vision Carlens (1949) has recently introduced a flexible double lumen soft rubber catheter The resistance of each channel is about one-fifth of that in a Zavod or Gebauer catheter Further a small rubber hook, which is released by a thread when the larynx is passed engages the carina and ensures the correct placing of the catheter without fluoroscopy The considerably decreased resistance of this catheter as compared with other types also allows a moderate degree of exercise while the catheter is in place

Let us consider the meaning and value of the data obtained by this method The ventilation vital capacity and oxygen uptake of each lung can be expressed as a percentage of the total under these conditions The ratio of the oxygen uptake of the two lungs is an accurate measure of the relative blood flow through them As the patient is breathing

high percentages of oxygen, the blood flowing through the lung will be fully saturated, no matter how poor the alveolar ventilation Thus, as the oxygen content of the blood entering each lung is the same, and the blood leaving each lung is fully saturated, the oxygen uptake of each lung will be a measure of blood flow through it In normal subjects the right lung usually has a ventilation, oxygen uptake and vital capacity which is about 55 per cent of the total Occasionally this figure is even higher and in some cases the left lung may show about 55 per cent of total function Thus only figures of 40 per cent or below on either side can be considered really significant

If air is breathed and the expired gas collected on each side, the oxygen uptake can be even more accurately determined However, the simple application of Fick's principle is no longer valid as the oxygen uptake on each side is affected by the relative efficiency of gas distribution to alveoli as well as by blood flow Under these more natural gaseous conditions there may be vasoconstriction and decreased blood flow in underventilated lung There is a real possibility that the administration of oxygen may artificially increase the percentage of blood flow through an underventilated lung by eliminating such vasoconstriction

When bronchospirometry is performed it is usually in order to determine, firstly, the function of diseased lung, which is to be collapsed or resected, and secondly, if possible, the function of the lung that will remain after operation The latter is the more important as the safety and the comfort of the patient will depend upon it Before considering how bronchospirometry will help answer these problems, it must be emphasized that such studies only measure the relative function of the two lungs at rest and in no way indicate the functional capacity and reserves of either lung A person with severe bilateral emphysema, if tested by this technique, would show oxygen uptake, ventilation and vital capacity of each lung to be within the normal limits Further, if one side developed severe bullae, then the percentage oxygen uptake and ventilation on the other side would increase well above the normal percentage Yet if the bullous lung were removed the patient would probably die of acute respiratory insufficiency

Returning to the consideration of the function of the more markedly diseased lung which is, if possible, to be collapsed or resected , in a number of instances (severe tuberculosis, bronchiectasis) the ventilation, oxygen uptake and vital capacity are negligible Only a small amount of air and blood enter the lung and it can be safely assumed that it is virtually functionless and that little alteration in the patient's status will result from its removal The fact that nearly 100 per cent of ventilation and oxygen uptake is carried out by the other lung does not prove that it is a healthy lung Nevertheless, its true functional capacity can be assessed adequately by studying the patient's exercise tolerance and ventilatory capacity Again the assumption that the remaining lung will function as well after the operation as before is only valid if the remaining lung is not injured or deformed

Unfortunately many cases under consideration are not so clear-cut as this If the diseased lung that is to be resected or collapsed shows 25–50 per cent of total function, then the clinician concerned still has a considerable problem It is often suggested that, on more marked exertion, the affected lung will not be able to continue to carry out such a high proportion of ventilation and oxygen uptake Such an attitude, and it is a reasonable one, may lead to resection in " border-line " cases It is very natural to want the organ which is to be removed to be relatively functionless However, Carlens (1950), using his new type of catheter, has been able to exercise patients considerably and obtain satisfactory tracings These experiments have shown remarkable constancy of the ratio of ventilation and oxygen uptake in all degrees of activity This is a very important observation and demands more realistic thinking It means that, despite the disease present, collapse or

resection often demand a high price in terms of function and care must be taken that this price can be paid and that the remaining lung will have adequate function to make life tolerable

Reliable estimation of the functional capacity of the other lung after resection is very difficult and bronchospirometry will be of little help The history of previous disease in this lung of asthma or of chronic bronchitis with cough over a long period, will call for great caution The present ventilatory capacity can be studied and an estimate of the effect of the resection on this can be made as previously described.

Occasionally it is found that the diseased lung is carrying out more ventilation and oxygen uptake than the lung which appears to be healed or is now radiologically clear In such cases there is almost invariably a history of pleural disease Healed bronchial stenosis may give rise to a similar situation It has been shown by many investigators (Pinner 1942) that so-called parenchymal disease which may be quite extensive, frequently interferes but little with ventilation and oxygen uptake whereas old pleural disease (i e pneumothorax with fluid and long delay in re-expansion) although showing little radiological abnormality often causes gross impairment of ventilation and oxygen uptake It is in this type of case where one lung has been diseased, particularly with pleural involvement and now appears healthy and the other lung requires collapse at a later date that bronchospirometry is so valuable

It should be made clear that bronchospirometry is not necessary or feasible in all cases where resection or collapse are being considered. It is only in those patients who have had bilateral disease or are suspected to have loss of function in the other lung due to a generalized lung disease such as emphysema that this procedure should be used. Although bronchospirometry will not entirely solve the problem it will often give most valuable additional data The most promising methods of assessing the actual quantity of functioning lung are those measuring the diffusing capacity The carbon monoxide techniques (Filley 1954 Forster, 1954) promise to be the most suitable for clinical work The relation of the differential broncho-spirometric studies to the total diffusing capacity and even the determination of the separate diffusing capacity of the lung to be left after operation are almost certainly the next important advance in this problem The routine studies of ventilatory capacity ventilation during walking of the right heart and of arterial blood saturation should always be available Careful clinical examination and consideration of the patient's history and present respiratory function in everyday activities must never be forgotten as they remain of cardinal importance despite the increasing attempts to quantitate the patient's disability

Methods

Ventilatory Studies

(a) *Ventilatory capacity* An ordinary Benedict spirometer is usually employed to determine the maximum breathing capacity and a tracing is taken. The bell should be reasonably light and the spirometer well balanced with ball bearing suspension. Resistance should be kept to a minimum and wide non-corrugated tubing used. No canister or valve is necessary the rebreathing of air being advantageous as it prevents unpleasant symptoms due to the washing out of carbon dioxide A tracing can be obtained which gives a permanent record of the rate depth of breathing and of any rise in the respiratory level.

The patient is told to breathe as much air as possible for fifteen seconds and can be

allowed to choose his own rhythm providing it exceeds 70 respirations per minute An initial demonstration and several less violent practice-runs are advisable Continual exhortation, at the rhythm adopted, imparts a sense of urgency and the need for maximal effort If possible the same observer and apparatus should be used for all cases as well as for the determination of the normal range

If hyperventilation causes violent coughing, codeine can be given before further attempts are made Should the observer consider that the lung conditions are such that the unnatural and violent respirations may cause aspiration of actively infected material into healthy lung (i e large tuberculous cavity on one side, being studied prior to thoracoplasty or resection), then the patient can be asked to take only three or four rapid and forced respirations using a high-velocity tracing The ventilatory rate for each breath is measured in litres per minute The highest value should be recorded This gives values remarkably close to the maximum breathing capacity measured over 15 seconds The measurement should be in the erect posture

(*b*) *Ventilatory demands* The measurement of the volumes being ventilated in any state of activity is very simple The patient wears a mouthpiece which is strapped round the neck, and a nose-clip The mouthpiece is attached to a " box " with non-return valves, the expired air passing down a tube into a Douglas bag being held by the observer The subject breathes in and out to atmosphere until he is in a steady state and then switched to the Douglas bag and the expired air collected over a minute or more

The exercise can consist of walking at a standard speed up and down a corridor, or on a treadmill, with variable speed and inclination Baldwin, Cournand and Richards (1948) have devised a standard minute step test, in which, although the patient does not reach a steady state, the ventilation can be studied and compared with that obtained with normal subject If the expired air is then diverted to a large collecting spirometer (Tissot), the ventilatory volumes can be studied during recovery The ventilatory volumes, especially when stated as a percentage of the maximum breathing capacity, that cause various degrees of dyspnoea can then be determined Another advantage of this test is that it is so short that even considerably disabled persons can carry it out satisfactorily Many investigators take the opportunity of studying the arterial blood saturation at rest and during, or after, exercise while performing these ventilatory studies An arterial needle is inserted into the brachial artery and secured more firmly with strapping If threaded properly (see below) this affords no difficulty even on severe exertion

Important references concerning this subject are Hermannsen (1933), Cournand and Richards (1941), Wright (1944), Baldwin, Cournand and Richards (1948), Warring (1949), Comroe (1950)

Lung Volume Determination

The " closed circuit method ", measuring the dilution of an inert gas, is recommended using Herrald and McMichael's (1939) important modifications These are, firstly, keeping the volume of the circuit constant by running in oxygen at the rate of uptake, and, secondly, the measuring of the rate and degree of dilution of the inert gas by means of a katharometer This instrument measures concentration by the change in the thermal conductivity of the gas in the circuit These workers used hydrogen, but helium, which is safer, is now almost universally employed It was first suggested for this purpose by Meneely and Kaltreider (1941) The care and maintenance of the katharometer presents no difficulties and any normally intelligent person can be trained in this method in a very short time There is some difficulty in obtaining the katharometer (Cambridge Instrument Co) and, if a Tissot

spirometer (Siebe Gorman & Co Ltd.) is available then the oxygen wash out method of Darling Cournand and Richards (1940) can be used It is a simple method and although on theoretical grounds it has more errors the results obtained are remarkably close to those obtained by other techniques Further a Tissot spirometer is an essential piece of equipment for any good respiratory laboratory as it is used for measuring volumes of gas rapidly and for collecting expired air to determine the oxygen uptake and respiratory quotient in all types of investigation (gas tension studies cardiac output determinations etc)

Important references in this subject are Christie (1932) Herrald and McMichael (1939) McMichael (1940) Darling Cournand and Richards (1940) Fowler (A Review of Methods 1950)

Study of the lung circulation and right ventricle

The advent of cardiac catheterization allows the precise study of right heart and pulmonary artery pressures Clinical examination, X rays and fluoroscopy will give invaluable information concerning the size of the right ventricle This aspect is well described in many standard text books dealing with heart disease Electrocardiographic studies of the right ventricle are now vastly improved in accuracy with the advent of the augmented unipolar limb leads and praecordial leads (Myers 1948 Johnson 1950)

The present paucity of knowledge concerning the right heart and pulmonary artery pressures in various lung diseases and after resection will continue so long as chest physicians consider this subject the province of the cardiologist Cardiologists are able to assess the state of the heart but are rarely able to relate this to the changes in the lungs and impairment of function Cournand s Hamburger Memorial Lecture (1950) is to be recommended for a review of this subject and gives the important references

Arterial blood studies

Arterial puncture This is described in some detail as there is little published information concerning the procedure The direct sampling of arterial blood is an important advance in respiratory physiology Although practised many years ago it is only recently that arterial blood sampling has become a frequent procedure in many centres It is quite amazing to what lengths some workers will go to avoid arterial puncture which with practice is painless and relatively easy The use of the indwelling needle (Cournand type or Riley modification) so that arterial blood can be sampled simultaneously with other gas and blood collection or even during exercise is also a great advance

The brachial artery should be used for this purpose for many reasons Patients are accustomed to venepuncture in this region and are not disturbed Femoral artery puncture causes greater apprehension and, in any case the risk of damage to this artery is unjustifiable in view of the more critical blood supply of the lower limb in later life Furthermore vigorous exercise can be carried out without disturbing an indwelling arterial needle in the brachial artery

The artery should be carefully palpated, as it lies medial to the biceps tendon and its course determined A small amount of novocaine is injected into the skin over the point of entry and more anaesthetic is injected down to and round the artery Large quantities are not necessary No attempt should be made to infiltrate the wall of the artery as this is almost impossible and quite unnecessary The arm is held supine and in extension there is no need for extreme extension unless there is considerable difficulty in entering the artery It is useless to attempt arterial puncture unless the artery is clearly felt With

the left index and second finger fixing and marking the course of the artery, the needle is inserted at the level of, or just below, the medial epicondyle Attempts to puncture the artery higher are often unsuccessful as the direction changes rather rapidly, and variably

The stilette is removed from the needle and, holding it by the flange, it is inserted down towards the artery Entry into the lumen is at once appreciated by arterial spurting The stilette is then threaded down the needle, taking care not to displace its point The blunt end of the stilette goes well past the point of the needle and passes along the lumen The whole needle can then be confidently threaded up the artery for a considerable distance until the flange of the needle tightens against the skin It is possible to thread the needle up the artery without the stilette but this is messy and may damage the intima The needle can then be strapped to the arm, although this is not absolutely necessary It can be left *in situ* for two to three hours and, although not encouraged to do so, the patient can flex his arm with considerable impunity

If the first attempt is not successful the needle should be withdrawn and a clean attempt made again from skin level, after checking the course of the artery carefully It is undesirable to " dig and delve " around the artery at depth and it is difficult to create a new " track " from an unsuccessful attempt

If, during anaesthesia or puncture, the patient should complain of tingling in the hand, the needle should be removed from the offending zone The author has never seen even a transient peripheral nerve disturbance after arterial puncture Very rarely, definite arterial spasm will be encountered after the needle has been inserted and the patient complains of " Raynaud-like " symptoms He can be reassured as this passes off in a few minutes

Haematoma is rare and usually caused by transfixing the artery unintentionally Most beginners go far too deep and would appear to believe that the brachial artery lies in the back of the arm

After removing the needle there is usually a brisk flow of blood for about a minute which is easily controlled by firm but not violent pressure The artery can be gently rolled under the fingers and in a short time, bleeding ceases and a dressing is not necessary Some rather apprehensive persons attempt to occlude the artery against the bone This is not only unnecessary but exceedingly painful and not without danger as it may cause syncope or cardiac irregularity, particularly in elderly patients with a tendency to cardiac arrhythmia

Respiratory studies are unusual in small children , if, however, an arterial blood sample is required, it is advisable to puncture the femoral artery, as entry into the brachial artery presents some difficulty

Collection and analysis of arterial blood The blood can be collected directly into a well-fitting syringe About 8–10 drops of heparin solution (10 mg /ml) are introduced before sampling and after rinsing it up and down the barrel to wet the walls the plunger is then pushed home so that only the small dead space contains heparin This is quite enough to prevent clotting of 10 c c of blood and avoids the inevitable bubble from the nozzle of the syringe The syringe usually fills without traction on the plunger If strong negative pressure is necessary the puncture is unsatisfactory and, in any case, will " pull " gases out of the blood If the syringe plunger is not too snug then it can be lubricated with a minimum amount of paraffin, but this should be avoided if possible A drop of mercury is introduced by dipping the end under mercury and drawing a small quantity into the blood After checking that there are no bubbles the syringe is then well sealed with an orange stick and then shaken to ensure mixing with the heparin

After sealing the syringe the blood is anaerobically isolated and can be kept on a roller to prevent sedimentation Samples can then be transferred into pipettes for analysis when required It is hard to believe but many workers still transfer this beautifully sealed blood to another vessel under paraffin oil Carbon dioxide can travel through paraffin to atmosphere at a high rate and this will greatly alter the gaseous properties and pH of the blood Further it is a quite unnecessary extra manipulation sedimentation of red cells occurs and efficient mixing and good representative sampling from under the oil is impossible If the blood cannot be analysed for a number of hours it is desirable to keep it in a refrigerator or an iced vessel particularly in warm weather Under these conditions the red cells will sediment almost completely and at least two minutes shaking is necessary before taking a sample for analysis

The determination of oxygen and carbon dioxide content is best carried out with the Van Slyke manometric apparatus (Peters and Van Slyke 1932) This is by far the best method and is not technically difficult It is best to have two of these apparatuses working and all persons concerned should be able to use them. It is wise to purchase the apparatus from a reputable firm and be advised by a worker in the field There are a number of modified forms which are most unsatisfactory (shallow manometer curves unsatisfactory cocks incorrectly shaped chambers)

During the last five years spectrophotometric techniques of analysing both the oxygen content and capacity of blood have become widely used in clinical practice and research They depend upon the different absorption of light by reduced and oxygenated haemoglobin Although the principles of this technique have long been known and used in physiological laboratories their widespread clinical use has only developed since it has been shown that relatively simple apparatus and spectrophotometers do not preclude considerable accuracy For a number of years the author and his colleague (Wade 1953) have analysed up to 70 samples of blood in 90 minutes by this technique Blood can be haemolysed and analysed in small tubes or injected through a simple system in the spectrophotometer Fresh blood can also be aspirated through a thin spiral of polythene in the spectrophotometer

This rapid technique is of particular value in studying congenital abnormalities of the heart where long and tedious Van Slyke analyses may still leave doubt concerning diagnosis if insufficient samples have been taken at certain sites during catheterization Occasional Van Slyke manometric estimations must still be carried out to assure that accuracy is maintained

Blood gas tensions

Blood gas tensions can be directly determined by equilibrating a small bubble of alveolar gas with the blood in a modified Roughton Scholander syringe The gas bubble is analysed in an attached graduated capillary tube after equilibration Blood gas tensions are mainly studied by persons carrying out fundamental research It is a difficult technique (Riley 1945) and it is advisable to see the analysis being carried out by a trained person before attempting to set it up in a new unit A great deal of time has been wasted by ignoring this advice

Bronchospirometry

Bronchospirometry is best studied by watching a good team at work The procedure is so near to the maximum of discomfort that a patient will reasonably tolerate that there must be no added unpleasant physical or psychological stimuli such as unnecessary noises coughing inexpert or careless manipulation or inadequate anaesthesia The spirometers

and respiratory circuits should be on a trolley All apparatus must be carefully checked and in perfect working order before the patient comes in Low resistance valves and light canisters can be used The total circuit resistance can be reduced by using pumps in each circuit (Knipping) Satisfactory pumps are not easy to obtain

It is usual to carry out a preliminary bronchoscopy Ulceration of the trachea or left main bronchus is a contra-indication to bronchial catheterization Deformities of the tracheo-bronchial tree can be studied The finding of bronchial stenosis will greatly help in the interpretation of results and decisions concerning resection Other contra-indications to bronchospirometry are recent spread of tuberculosis, pulmonary haemorrhage in the previous two weeks and recent laryngitis, tracheitis or bronchitis Routine external spirometry is best carried out beforehand, as these procedures are invaluable training for the patient apart from the important data they yield

If the patient is producing a great deal of sputum, an initial course of postural drainage should be carried out This allows more efficient anaesthesia and there is less chance of catheter blockage A sedative (amytal gr iii) should be given Some workers favour $\frac{1}{4}$–$\frac{1}{6}$ grain morphine sulphate half an hour before Large doses of morphia must be avoided The tongue, fauces and pharynx are then anaesthetized by painting with 5 per cent cocaine hydrochloride A brush allows more precise and economic use of the anaesthetic The pyriform fossa and larynx are then anaesthetized and finally 1 c c of solution is injected with the patient leaning to the left and 0 5 c c with the patient leaning to the right Anaesthetization should be carried out slowly, calmly and thoroughly It is imperative not to lose the patient's confidence and good anaesthesia is the key to successful bronchospirometry

There are several methods of introducing the catheter and a metal guide is usually provided However, except with the Carlens catheter, a guide is not necessary in properly trained hands After passing the larynx the final placing of the catheter tip in the left bronchus is carried out under fluoroscopic vision The tip should be just medial to the heart border and about 3 cm from the carina The inflation of the balloons by an air-filled syringe is controlled by a manometer attached to the appropriate channel This is a very critical juncture as the patient will feel the full resistance of the catheter and the balloons may stimulate coughing Before commencing any observation, the left upper lobe must be checked for air entry by auscultation It is easy to occlude this upper lobe bronchus by passing the catheter a little too far This auscultatory test is unreliable and the careful placing of the catheter is the only adequate precaution This is a great advantage of the carinal hook on Carlens' catheter as it prevents the catheter slipping before the balloons are distended

Spirometer recordings should be started as soon as possible If the lungs are not separated then the whole system is a common chamber and one spirometer will empty into the other, as even the more minute differences of resistance will cause such transfer This will result in the tracing either diverging or converging If the tracings are satisfactory they should be continued for at least five minutes This will allow a reasonably accurate measurement of the slope of the tracings It is unwise to measure uptake from shorter tracings particularly as the first minute is usually unstable Before terminating the test the vital capacity, inspiratory capacity and expiratory reserve volumes of each lung should be determined In some cases, if the patient is relatively comfortable, mild leg exercise against resistance is carried out, the change in ventilation and oxygen uptake being noted Usually the patient will not tolerate a very great increase in activity, but Carlens' catheter allows considerable exercise to be performed This is an important advance and should add greatly to the value of bronchospirometry

On removal of the catheter the vital capacity should be measured at once with an ordinary mouthpiece, as comparison of this figure with the added vital capacities of the two lungs is a useful check on the reliability of the recordings Finally (Michelson and Wright 1950) there is no evidence of reactivation or spread of the tuberculous disease by bronchospirometry

The above account is of necessity very brief and readers are recommended to study the procedure in further detail (Wright 1950 Pinner 1942 Donald 1952)

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CHAPTER 3

THE ASSESSMENT AND PREPARATION OF PATIENTS FOR MAJOR THORACIC OPERATIONS

Neither careful physiological estimates nor clinical impressions as yet provide accurate indications of the capacity of the patient to withstand major operations the new born baby of a few days tolerating such a serious operation as the repair of an oesophago tracheal fistula and the old man of 75 who survives an excision of the oesophagus indicate that age plays a relatively small part in selection In fact, the slowly metabolizing elderly patient may suffer less physiological upset than the active healthy adult and it is unwise to fix arbitrary standards such as those which exclude pneumonectomy for carcinoma of the lung in patients over 60 indeed the slower rate of tumour growth in that decade often provides the longest survivors The obese plethoric middle-aged man is a more formidable risk than the very young or very old Children stand thoracotomy better than laparotomy and age itself is no bar to necessary interventions It may be wise to defer lobectomy for bronchiectasis until the child is old enough to co-operate intelligently with the physiotherapist and nursing staff in the pre and post-operative stages but such a consideration does not weigh if the resection indicated is a total extirpation of the lung such a pneumonectomy may be indicated at the earliest age if total bronchiectasis or cystic disease is a menace to life or is delaying normal physical and mental development

The general condition

The psychological and physiological states are of obvious importance The combination of extreme nervousness with anoxaemia due to lung or cardio vascular disease is often a deterrent to surgery unless there is considerable evidence that operative treatment will correct the underlying cause of the oxygen lack. Renal disease may be a serious contra indication especially in operations such as oesophagectomy which may gravely disturb the protein and electrolyte balance of the blood Diabetes is no reason for excluding operations especially in pulmonary tuberculosis when the indication is for collapse or resection procedures as the dangers of coma and infection can be dealt with by insulin and antibiotic therapy the control of the tuberculous lesion often plays a great part in helping the diabetic treatment With the increased use of streptomycin many of the florid exudative lesions that develop in the diabetic show a tendency to fibrotic healing which may call for surgical help

Pre-operative preparation

Apart from the surgical treatment of tuberculous disease the patient who is to undergo major thoracic surgery should be in the ward for two or three days before operation Not only is the rest of great value in patients with disordered thoracic function but the time is well spent in adjusting them to the atmosphere of a ward where much active pre and post-operative treatment is proceeding in a way not without its *alarming effects to the* newcomer ! From the earliest moment the quiet explanation of the basis and need *for* these measures is begun and represents the essential collaboration between nursing staff physiotherapists surgeon and anaesthetist

The clinical assessment

The history taking and clinical examination must be thorough and unhurried. This is the basis for diagnosis and provides the chief method of assessing the need or otherwise for operation; a surprising number of the histories are typical of the thoracic condition; note the frequency of repeated attacks of "pneumonia" in the patient with bronchiectasis and the persistent production of sputum, usually exaggerated after coryza, or the often heard story of "pneumonia" that improved with penicillin treatment and then relapsed (carcinoma of the bronchus!). Since diseases of the thorax may be the source of lesions elsewhere or because the thoracic viscera themselves may be secondarily invaded, the examination must follow the routines imposed in any medical ward: the metastases of tumours or infections to the brain are specially indicative of the need for a neurological examination in detail in the patient with a suspected lung tumour, lung abscess or bronchiectasis.

Patients with long-standing lung or pleural sepsis are naturally toxaemic. So used may they be to chronic ill-health that many of them do not appreciate the handicap under which they have lived until the sepsis has been cured. The attempt to obtain from them a history of ill-health, lassitude and loss of appetite may fail but the appearances are often typical; the state of the skin, the pallor, listlessness and apathy often confirm a picture of gross secondary anaemia proved by the blood examination. Finger clubbing is often an indication of severe cardiac or pulmonary disease but has oddly escaped the attention of most patients themselves.

In some patients with peripheral lung carcinoma severe joint and bone pains (pulmonary osteoarthropathy) may be the presenting part of the clinical picture. Occasionally pulmonary carcinoma may be responsible for neuropathies and peripheral neuritis in the absence of metastases; the patient may present a picture of myasthenia gravis or most rarely as one of Cushing's syndrome.

Amyloid disease

This is becoming increasingly rare but must be considered when patients with long-standing pleural sepsis are being assessed. It is seen most usually in modern surgery when there is a tuberculous element to the infection, its victims being typically patients with a chronic secondarily infected tuberculous pyo-pneumothorax. Its detection is important, not because it should be regarded as an inevitably irreversible process but because the energetic treatment of its cause provides the only hope of reversal (Vernon Thompson).

In long continued suppuration with protein loss the amyloid glyco-protein is laid down in and replaces the connective tissue around the vessels and cells of the organ affected: the spleen, liver and kidneys become increasingly bulky, their cell protein being slowly destroyed as a result of pressure atrophy by the *infiltrating amyloidosis*; other tissues and organs are affected including the lungs themselves. The albumen content of the plasma falls with an increase in the plasma-globulin.

The diagnosis depends largely on the suspicion that it may exist; the discovery of hepatic, splenic and renal enlargement in an advanced example of pulmonary tuberculosis especially with empyema would justify the diagnosis which is confirmed by biopsy. Although liver biopsy is the most reliable way of providing a specimen showing the characteristic histological appearance, it is useful to remember that a positive microscopical diagnosis can rarely be made from study of small biopsies taken from the mucous membrane of the gums. The urine will show albumen and hyaline casts.

The Congo red test depends on the absorption qualities of amyloid substance for this dye 15 c c of 0 75 per cent of freshly prepared aqueous solution of Congo red (the commercial type is dangerous for intravenous injection) is injected intravenously In amyloidosis the dye is quickly absorbed and so disappears from the circulating plasma in a healthy subject the dye can be detected in plasma samples as long as 10–12 hours after injection but in amyloid disease it is not found after an interval as short as 2–3 hours after infusion

Patients with a palpable liver spleen and kidneys may tolerate major procedures such as pneumonectomy or thoracoplasty surprisingly well If the interventions control or remove the lung or pleural infection the visceral enlargements may recede The operation of pleuro pneumonectomy *is preferable to staged thoracoplasties* because it provides a method of rapidly removing the effects of a gross infection of lung and pleura

The radiological examination

This is the first essential after the history and clinical assessment if surgery is to be contemplated an up-to-date radiological survey must never be omitted If the patient is adjudged to be too ill for radiological examination he is certainly too ill to be taken to the theatre except for the immediate relief of acute tracheal or bronchial obstruction by bronchoscopy or the relief of a tension pneumothorax by needle aspiration Thoracic operations should not be undertaken apart from the most severe emergency measures unless portable X ray photographs can be taken in the ward, as the study of these provides the *most important single measure in the post-operative control of the patient*

In addition to plain radiographs fluoroscopy is of the greatest assistance and should only be omitted if the patient is too ill. The study of the patient after the injection of *contrast media into the bronchial tube (bronchography) pleural empyemata (pleurography)* or into a vein or artery (angiocardiography) may provide essential and accurate information These auxiliary aids which should be regarded as part of the clinical examination are described elsewhere *Tomography and kymography also have a place in diagnosis*

Examination of the sputum

It may appear that this examination would be taken for granted but only too often information on this point is difficult to obtain. The daily amount of sputum should be measured accurately and entered on the temperature chart the macroscopic nature of the sputum is of obvious importance especial note being taken of the presence of pus and blood Routinely the sputum is submitted to bacteriological and histological examination there is much to support this type of examination for at least six consecutive days if the aim is to exclude a tuberculous lesion. The unexpected discovery of tubercle bacilli or of malignant cells is not a rare experience in a surgical thoracic ward.

The discovery of tubercle bacilli in one odd isolated specimen should not be accepted too lightly as providing positive evidence of active pulmonary tuberculosis In children and patients who deny the existence of sputum the examination of the faeces for tubercle bacilli may be of great value and should be carried out before recourse is made to gastric lavage The examination of sputum obtained directly from the bronchi during bronchoscopic examination may detect tubercle bacilli or malignant cells

Examples exist where a false diagnosis of pulmonary tuberculosis has been made on the discovery of acid fast bacilli which in fact were timothy-grass bacilli particularly so may this error be made in those cases of lung infection due to tracheo bronchial aspirations of oesophageal contents in such states as cardiospasm or pharyngeal diverticulum

Haematological investigation

The value of a full knowledge of the blood picture, the haemoglobin percentage, the amount and particulars of the plasma proteins, and the blood grouping is obvious The frequent necessity for large blood transfusions in thoracic surgery calls for the most exact matching of blood and a knowledge of the rhesus factor

With the prevalent use of antibiotic therapy the services of a skilled bacteriologist able to assess the sensitivity or otherwise of the organisms under treatment are essential Blood culture examination, the cytological and bacteriological assessment of pleural fluids and exudates and the estimation of blood sedimentation rates are frequently required

Physiological investigations [see Chapter 2 and Chapter 15]

BRONCHOSCOPY, OESOPHAGOSCOPY AND BRONCHOGRAPHY (page 160)

These investigations provide information of supreme value They are almost free from danger and are readily performed under local surface anaesthesia or with the help of relaxants and pentothal In addition to its diagnostic value bronchoscopy may be a life-saving measure when used for the aspiration of muco-pus or the removal of foreign bodies If the facilities and skill are not available for pre- and post-operative bronchoscopy there can be no justification for carrying out major thoracotomy

Technique of bronchoscopy

Anaesthesia Local anaesthesia has the great advantage of safety and rapid recovery so that the cough reflex is not abolished (a matter of considerable importance when pulmonary suppuration is present), and it assists in the technical ease of examination It may be carried out as an out-patient procedure, the patient being kept under observation for four to six hours after the bronchoscopy

Omnopon and scopolamine are injected at least one hour before the examination , the lips, tongue and gums are painted with a 10 per cent cocaine solution after preliminary tests for cocaine sensitivity In spite of its toxic effects cocaine is a more efficient local surface anaesthetic than amethocaine preparations, but these are adequate

The tongue is held forwards so that its dorsum, the palate, the uvula and the posterior pharyngeal wall can be painted thoroughly by means of a brush or of wool swabs held in a special forceps of which Brock's model is excellent This step should be deliberate and slow, the patient being encouraged to breathe a little more deeply than usual, as this diminishes the tendency to retch when the sensitive pharyngeal wall is painted After a pause the curved forceps holding a wool swab soaked in the surface anaesthetic is passed down each side of the back of the tongue in turn to reach the pyriform sinus , here the anaesthetic solution will soon anaesthetize the mucous membrane and the superior laryngeal nerve which lies just beneath it on the medial wall of the sinus The curved applicator is then held against the epiglottis When this has been anaesthetized a direct laryngoscope of the Magill type enables a view of the interior of the larynx to be obtained and a wool swab can be introduced into the glottis or 2 c c of 10 per cent cocaine can be run into the larynx through a laryngeal syringe This is probably preferable to the injection of the same amount through a crico-thyroid puncture into the larynx

General anaesthesia When indicated this is best done under pentothal and relaxants . this requires the services of a skilled anaesthetist The dosage, of course, should be sufficient

to obtain rapid laryngeal relaxation but an apparatus to provide oxygen under pressure and an efficient sucker must be in complete readiness before the pentothal and curare are injected intravenously *As soon as anaesthesia and relaxation have been achieved a few* breaths of oxygen under pressure should be administered, as in controlled respiration through a tight fitting face piece before the bronchoscope is passed.

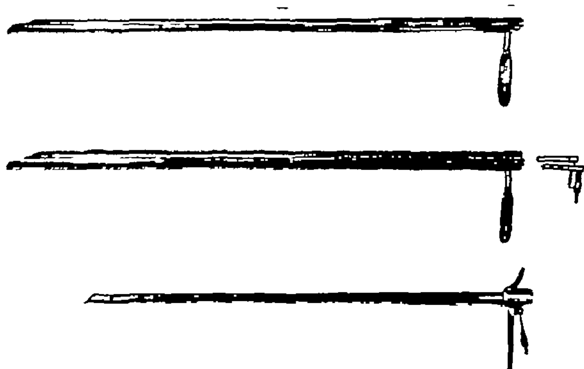
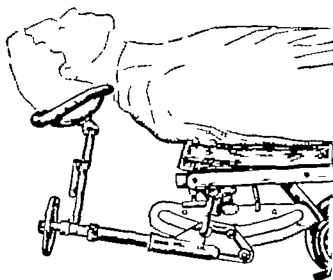


FIG 3 1 —The two upper instruments represent the oval Negus oesophagoscope with proximal lighting The lower instrument i the Negus bronchoscope which is provided with distal lighting.

The passing of the bronchoscope Special head rests are made and help in the ease of examination



[Genito-urinary Mfg Co

FIG 3 2 —Bronchoscopy position.

The bronchoscope can readily be passed with the patient sitting up (Fig 3 3), this is most useful as a post-operative measure in the treatment of a collapsed lobe whose bronchus is occluded by muco-pus A comfortable position for patient and operator is with the patient lying flat on the back with the shoulders partly over the edge of the table with an assistant supporting the head, if a special rest is not in use or available.

Whatever the position of the patient and whether a head rest or not is in use, the essential point is to have the head extended so that the occiput is well back and in such a position that the mouth and trachea are in a continuous straight line As soon as the



Fig 3 3 —Bronchoscopy and bronchoscopic suction in the ward for post-operative lung collapse A photograph taken during the course of an emergency bronchoscopy

bronchoscope is in the trachea, the head can be altered in position and the occiput is brought forward a little and the head moved from side to side

The bronchoscope can be passed directly into the larynx without first introducing a laryngoscope large enough to allow the passage of the larger instrument through it With the tongue held forward a little by the left hand the bronchoscope is passed until the epiglottis is seen this is gently displaced forwards by the tip of the bronchoscope which is then passed onwards through the glottis and cords If the surface anaesthesia has been adequate this is easy and painless

Points to note in the bronchoscopic examination

The cords and trachea are examined closely for evidence of diseases (inflammatory or neoplastic) and laryngeal nerve paralysis especially important is this in suspected carcinoma of the bronchus, as paralysis of one vocal cord and tracheal involvement by upward spread of the tumour may indicate inoperability

The carina is studied carefully it is usually sharp and clear in malignant disease of the lung it may be rounded and broad as the result of malignant invasion and enlargement of the inferior tracheo-bronchial lymphatic glands

The right bronchus The opening of the right upper lobe bronchus is easily seen if the head is held well over to the left side it appears as a rather oval opening below the carina A better view of the interior of this bronchus is obtained by looking with a right-angled telescope and the commencement of the subdivisions can be made out (Fig 3 4)

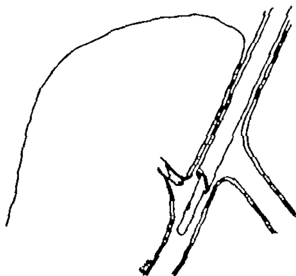


Fig 3·4 —Diagram of a right angled telescope viewing a tumour in the right upper lobe bronchus.

As the instrument is advanced down the right bronchial stem the middle lobe bronchial orifice will be seen about 1 cm below the upper lobe orifice and leading out of the front wall of the stem almost directly upwards or anteriorly Usually opposite to this at a slightly lower level will be seen the opening of the bronchus into the apical segment of the lower lobe a little further down there is no difficulty in studying the openings of the three basal segmental bronchi

The left bronchus This is not so easy to study as the right one because of its greater obliquity but if the head is held well to the right its upper lobe orifice and the segmental bronchial openings of the apical and basal segments of the left lower lobe are readily seen. It is not possible usually to see the lingular bronchial orifice but the carina between the apical and anterior segment of the upper lobe can be seen through the right-angled telescope

Complications of bronchoscopy

Trauma to teeth Wherever possible pre-operative dental care will have been carried out to include the removal of carious teeth and the scaling away of dental aggregations loose teeth in the upper jaw are particularly liable to dislodgement and bronchoscopy in the presence of gross paradental sepsis might carry infection into the bronchus

Laryngeal trauma This should not follow It is possible if the local anaesthetization is inadequate or too large an instrument is passed in children The post-operative effects may be a mild traumatic laryngitis or a considerable stridor the latter may be due to oedema actual cord injury or mucosal sloughs In children the stridor is accompanied by cyanosis a fast pulse and rib recession The immediate treatment is by steam bottles and an oxygen tent But if the condition does not improve rapidly steps must be taken to do a low tracheotomy The necessity for this may arise after bronchoscopy in infants when foreign bodies have been removed The problem in a children s hospital is gravely complicated at times when patients are seen in whom abortive attempts to remove foreign bodies in the bronchi have caused not only severe laryngeal oedema but have failed to relieve the collapse of the lung or lobe beyond the obstruction In such early attempts should be made to secure the foreign body through a bronchoscope and this may require tracheotomy immediately afterwards at the same operation

Haemorrhage A little bleeding is common after biopsy specimens have been taken from vascular tumours its occurrence is one of the arguments in favour of the use of local anaesthesia as its chief danger is represented by a flooding of the bronchial tree by blood

in the absence of an efficient cough reflex If noted at the time of the biopsy, the blood should be aspirated by means of a powerful sucker and direct pressure applied by means of a large swab held in special probes

Occasionally severe haemorrhage follows of which a few accounts of a fatal nature have been published these were chiefly in instances of biopsy done near the left upper lobe bronchus and in the region of the right middle bronchus If a tumour is seen or suspected in the left upper lobe bronchus great care is necessary not to include a portion of that bronchus in the biopsy forceps, as the pulmonary artery is close to it as it sweeps behind the upper lobe bronchus Similarly the middle lobe artery is close to the origin of the segmental bronchus to that lobe and may be torn if the biopsy bite is too deep

If bleeding is tending to be uncontrollable, as a last resort a Thompson blocker should be inserted rapidly to prevent the spill over of blood into the other bronchus

It remains to point out the obvious danger of bronchoscopy in patients with aneurysms of the aorta that may be pointing into the bronchus the pre-operative diagnosis of these may be that of bronchial carcinoma and the possibility of such a diagnostic error should be kept in mind As an extreme rarity an aneurysm of a patent ductus arteriosus may erode the left main bronchus but the clinical diagnosis of a patency will usually not have been difficult, though again it is well to remember that aneurysmal dilatation of the ductus Botalli has been regarded as a mediastinal or lung tumour

OESOPHAGOSCOPY

The investigation and treatment of diseases of the oesophagus requires endoscopic examination as a routine measure and a surgeon unequipped for oesophagoscopy should not undertake the surgical care of carcinoma, oesophagitis or cardiospasm The diagnostic confusions, so frequent in these three diseases if opinions are established only on radiological appearances, can be avoided if oesophagoscopy and endoscopic biopsies are employed In the treatment of peptic ulcer of the oesophagus, cardiospasm and fibrous stricture, satisfactory relief can often be obtained by oesophagoscopic dilatations The examination is simple, safe and provides reliable evidence

Technique of oesophagoscopy

Anaesthesia As in bronchoscopy, local surface anaesthesia carries great advantages, being safe and effective for certain manipulations in which the larger type of oesophagoscope is used, anaesthesia by pentothal and a muscle relaxant is valuable An intratracheal tube, through which oxygen is delivered, is passed before the oesophagoscopy

Food and fluids are forbidden for at least six hours before the examination An hour before the operation omnopon and scopolamine are given and half an hour later the patient is given a lozenge of amethocaine hydrochloride to suck The surface anaesthesia used is a 2 per cent solution of amethocaine, which is preferred to cocaine which might be swallowed The lips, tongue, palate and upper pharynx are sprayed or painted with the solution the tonsils, epiglottis and pyriform fossae are best anaesthetized by direct pressure of a swab soaked in amethocaine held in curved application forceps

Inhalation or basal anaesthesia is dangerous in patients with oesophageal obstruction because of the risk of tracheal inhalation during the induction The risks of this may be lessened if the patient is anaesthetized with the head and chest well propped up and if the oesophagoscope is introduced rapidly so that retained oesophageal contents can be aspirated

quickly through a large bore aspirating tube attached to a powerful sucker a cuffed intratracheal tube should be employed when general anaesthesia is being used to prevent any risk of inhalation of oesophageal contents

Position of the patient As in the case of bronchoscopy a special head rest may be employed but is not essential and I prefer to have the head held With either method the head and shoulders must be well clear of the edge of the table so that the upper half of the scapula just reaches to that point The neck should be in front of the plane of the body with the head flexed backwards at the occipito-atlantal joint

Two instruments are in common use the smaller circular Irwin Moore oesophagoscope with distal lighting and the larger oval pattern of Negus which has proximal lighting and allows more room for good visualization and instrumentation of the oesophagus Because of its greater bulk it is more difficult to pass than the Irwin Moore type but with good anaesthesia and a co-operative patient this can be overcome Its use is valuable if hydrostatic dilatation of the spastic area of the oesophagus in cardiospasm or the placing of a Souttar s tube is to be carried out

Passage of the oesophagoscope The upper teeth and lip are protected by the left hand a full view of the epiglottis must be obtained before any attempt is made to negotiate the upper sphincter of the oesophagus (the crico-pharyngeus muscle) which lies behind the cricoid cartilage The tip of the instrument is gently lifted forward to engage the anterior wall of the oesophageal entrance and the right hand exerts gentle pressure until the sphincter gives The direction of the force should be anteriorly so that the cricoid cartilage is lifted forwards if this is not done with the greatest care the instrument will tend to press against the posterior pharyngeal wall which is vulnerable as it lies rigidly against the front of the bodies of the cervical vertebrae it is in this posterior wall that most of the recorded tears have been reported. As soon as the crico-pharyngeus muscle has been passed the lumen of the oesophagus usually containing a little frothy fluid is easily visible

If the upper opening of the oesophagus appears small and difficult to enter a small gum elastic oesophageal bougie is passed through it and the oesophagoscope is passed along the line so indicated Throughout the further downward passage of the instrument a clear view must be obtained and for this good lighting of the instrument and the use of an efficient sucker is essential.

When the instrument is beyond the level of the aortic arch the head is allowed to drop down and to the right As soon as the instrument has passed through the cardia gastric juice flows back into its lumen Under local anaesthesia the pinch cock mechanism of the right diaphragmatic crus can be studied easily the contractions of the muscle fibres during each inspiration being readily seen and its efficiency or insufficiency noted (see hiatus hernia ' Chapter 26)

The abnormal conditions that may be studied are described in the section on diseases of the oesophagus and of the diaphragm (Chapters 19 26) It would be pedantic and un necessary to say today that all foreign bodies should be removed by the oesophagoscope as soon as possible to avoid any dangers of ulceration with the sequel of mediastinitis

The complication of rupture of the oesophagus during endoscopy

A tear of the oesophagus just below the crico pharyngeus muscle may occur especially in elderly people with osteo-arthritis of the cervical spine and not usually diagnosed until a few hours later when difficulty in swallowing is accompanied by pain and tenderness in the neck A lateral radiograph will show air pushing the oesophagus and trachea forwards Much later emphysema of the neck or a pneumothorax may be noted Unless immediate

surgical exposure and repair is carried out late complications such as mediastinal abscess and oesophageal stricture may follow Although examples of cure by expectant measures have been reported this method of treatment is too risky for recommendation If the tear is pharyngeal only and manifested by pain on swallowing and supra-clavicular emphysema on the day after instrumentation, a conservative policy may occasionally be justified , feeding is by a milk drip through a Ryle's tube and full doses of penicillin and streptomycin are given

The lower oesophagus may tear spontaneously or be lacerated during oesophagoscopy for stricture or carcinoma Severe lower thoracic and upper abdominal pain with rigidity develop and the diagnosis may be confused with that of coronary thrombosis or an upper abdominal catastrophe Rapid confirmation of the diagnosis is made by radiography which will demonstrate a pneumothorax (as the pleural cavity is usually involved) or air in the mediastinum These patients, whether the tear is spontaneous or due to accidental instrumentation, should be treated by immediate thoracotomy and repair of the laceration Without operation only a few survive and develop an empyema drainage of this may allow the fistula to close

PHYSIOTHERAPY

The use of physiotherapy will do much to improve the general health of the patient, increase vital capacity and reduce purulent bronchial secretions when these are present In the post-operative phase continuance of such measures will only be possible if the patient

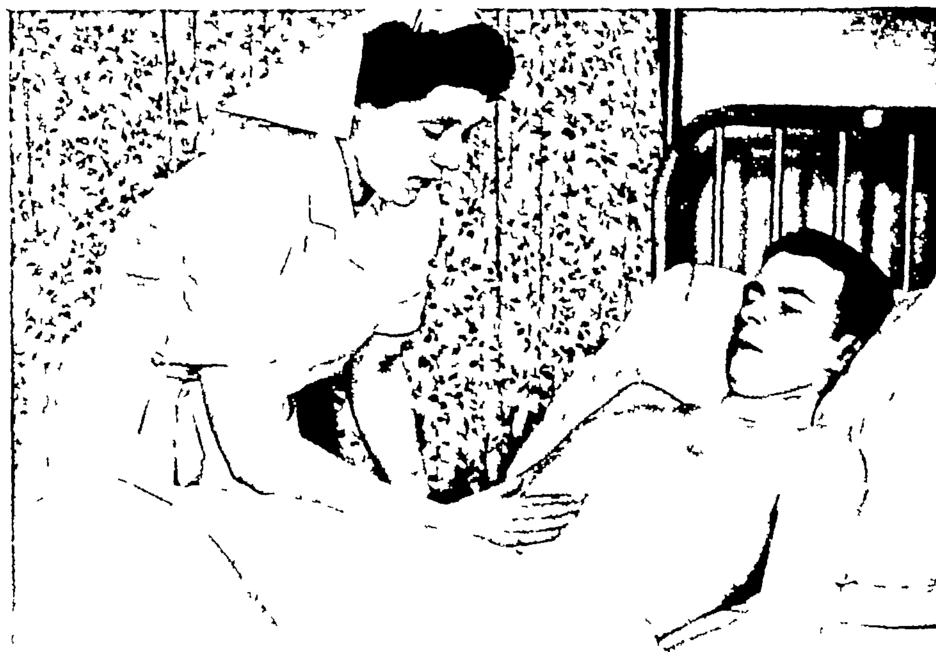


Fig 3 5—Unilateral breathing being taught

has full confidence in the methods that have been taught him before operation and if he co-operates in the matter of correct posture, active functional movements of the diaphragm, chest wall and the accessory muscles of respiration and the efficient expectoration of bronchial secretions The more efficient the physiotherapy the less frequent will be the need for post-operative bronchoscopic suction for the correction of atelectasis

The methods adopted are applicable to the ward as a whole but individual attention to each patient is also essential The surgeon should discuss each individual patient with the physiotherapist and rigid routines are unwise A patient with unilateral pulmonary tuberculosis who is to undergo thoracoplasty or resection may need unilateral breathing exercises confined to the sound side and a good physiotherapist can achieve this without breaking the rule of local rest applied to the lung affected by the disease Patients with carcinoma of the oesophagus with severe malnutrition often have little capacity for vigorous exercises suitable for a young adolescent with bronchiectasis and the regime for each patient is arrived at by joint consultation

Physiotherapy being a profession in itself requiring a long training in study and technique it is not possible for a surgical writer to do justice to the subject and the outline given below is intended for the guidance of physicians and surgeons who are perhaps unacquainted with the value of this thoracic treatment

Bronchiectasis and lung abscess

Adequate time should be spent on pre-operative treatment in the ward if the amount of sputum has not been decreased to manageable proportions operation should be delayed until this has been achieved The pre-operative plan includes postural drainage breathing exercises the correction of deformities (thoracic and spinal) and general exercises

Postural drainage Although bronchiectasis is usually a basal disease the advice that

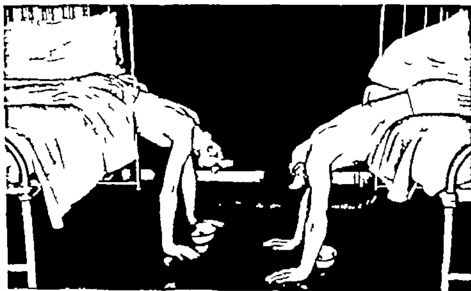


Fig 3·6 —Thoroughly unsatisfactory positions for postural drainage
Such are exhausting and only drain part of the lungs.

the patient should lean over the bed twice a day is quite futile Fig 3 6 illustrates a bad type of postural drainage it fails to drain all the lower lobe segments and is ineffective in the emptying of secretions from the right middle lingular and upper lobes the position is uncomfortable and exhausting to ill patients In most patients with bronchiectasis the moistness of the various segments cannot be related entirely to bronchographic appearances in children especially it is important to drain posturally every segment and this can be achieved by using the different positions shown in Fig 3 7

If the physiotherapist encourages active coughing and employs light percussion after each position has been adopted for a few minutes the bronchial passages are more effectively

cleared than by long wearying periods spent in one position over wedges or on special postural drainage beds Such devices tend to encourage the adoption of uniform unimaginative routines, being too passive and extremely dull for the patients Obviously the segments containing the bronchiectasis or the lung abscess will call for the most careful and prolonged drainage At no time should the patient be exhausted by too vigorous a regime, constant encouragement and explanation together with his own observations on the daily decrease in the amount of sputum will soon indicate that the treatment is worth while

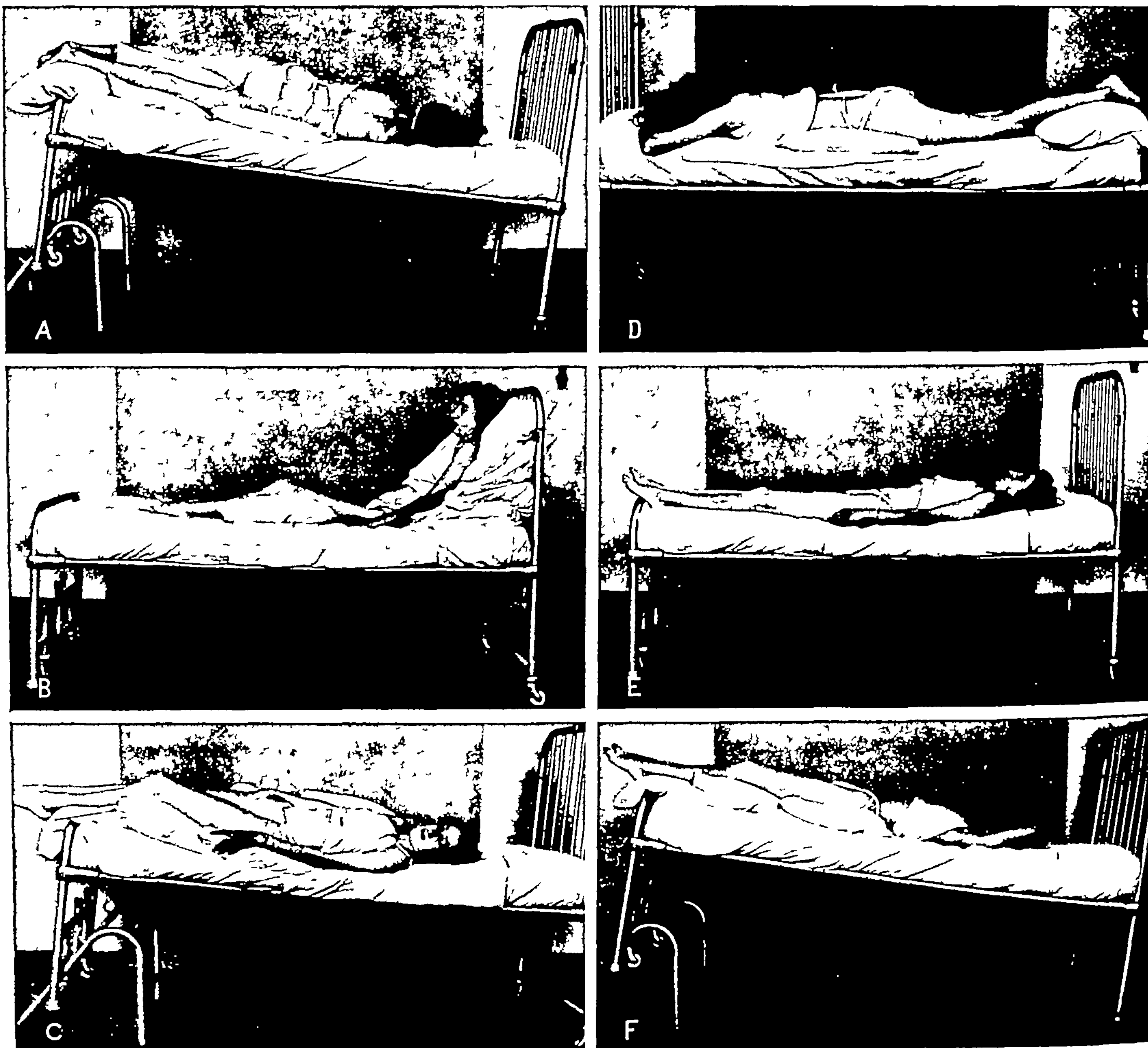


FIG 3 7—Positions for postural drainage of individual segments

(A) Left lateral and posterior basal segments
(B) Apical segments of upper lobes
(C) Right middle lobe
(D) Apical segments of lower lobes
(E) Anterior (pectoral) segments of both upper lobes
(F) Anterior parts of both lower lobes

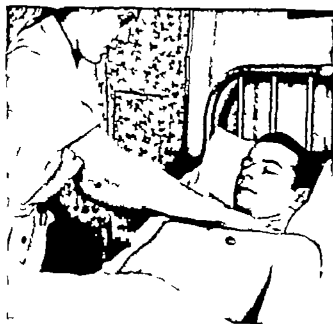
Breathing exercises Most thoracic surgical patients have diminished chest movements in all areas and not those confined to the area of disease frequently they have unconsciously adopted the habit of shallow breathing as this decreases the tendency to cough The diaphragm rarely descends to its full unimpaired degree Ventilating movements are



(a)



(b)



(c)



(d)

FIG 3 8

(a) and (b) Chest exercises.
( ) Inspiration; (b) Expiration.

(c) and (d) Upper chest exercises.
(c) Inspiration (d) Expiration.

especially poor in patients who have been confined to bed for long periods The aim in the pre-operative period is to encourage full movements of the areas of the chest most affected by disease, to teach the value of diaphragmatic contraction and relaxation, to correct postural deformities and to increase the venous return to the heart

Most patients have great difficulty at first in learning to aerate fully the bases of the lungs because they have relied for a long time on upper respiratory movements The physiotherapist therefore starts by teaching diaphragmatic control The next phase is to teach the patient to ventilate and empty as far as possible the different areas of the lung Coughing in the nature of convulsive exaggerated movements must be avoided, many patients tend to force the chest forwards or laterally by active spinal column movements which are, of course, quite ineffective though giving the uninitiated patient the feeling that he is moving mountains of air! This type of error can best be eliminated if the technique of *pressure expansion exercises* (see Fig 3 8) is followed, by breathing against moderate pressure provided first by the physiotherapist's hands and then by his own the patient can estimate and appreciate the effects of his own breathing efforts and will soon learn the need for concentration during the various manœuvres of breathing required Direct pressure can steady weak or painful areas while the breathing areas to be inflated are under attention Throughout this exercise the patient should be in a comfortable position far removed from the regimented posture of the old Fowler position

Under good tuition the co-operative patient soon learns to control his breathing so that at will he can ventilate a lung or single lobe more fully than their counterparts sited elsewhere, this is of special value in pulmonary tuberculosis where increased movements of the diseased side or lobe may be undesirable The combination of postural drainage and of breathing exercises not only improves the general condition pre-operatively but the patient educated in their use will continue them in the post-operative period when they assume an even greater value

PRE-OPERATIVE CHEMOTHERAPY

The principles of asepsis and antisepsis, of careful technique with the avoidance of haematoma formation and the prevention of widespread contamination when septic organs such as the oesophagus or bronchus are opened, by preliminary skin cleansing, the use of skin towels and all the customary aids to careful precise operating govern all surgical procedures The adoption of pre-operative antibiotic therapy in thoracic operations is directed chiefly against the pathogenic organisms universally harboured by the respiratory and oro-pharyngeal passages Penicillin injections are given for 24 hours before most surgical interventions and continued in the post-operative period In operations on the heart or great vessels this period should be lengthened to 48 hours, as every measure possible should be taken to limit any risk of bacterial endocarditis Antibiotic therapy in lung abscess, pulmonary tuberculosis and subacute bacterial endocarditis has a far wider place than mere pre-operative use

The wide range of antibiotics now available has provided a bewildering choice, the indiscriminate use of those that destroy the normal bacteria of the alimentary tract may produce severe diarrhoea and grave nutritional upsets Such powerful agents should be reserved for infections that have been subjected to adequate bacteriological study *Routinely if prophylaxis is the aim, penicillin and streptomycin remain the most valuable agents*

Antibiotics in the pre-operative operative and post-operative phases have probably decreased the incidence of pleural infection after major thoracic operations The general acceptance of this calls for no prolonged arguments on the value of antibiotics but their undoubted efficiency is no reason for the abandonment of scrupulous surgical techniques that are the safest prophylaxis against post-operative sepsis Indiscriminate use of antibiotics is wasteful and may cause unnecessary discomfort to the patients because of the many injections required The choice of effective antibiotic agents in the treatment of established pre-operative pre-existent infections can be largely made on the bacteriological study of sensitivity or resistance of the organisms in the sputum or from aspirated pleural exudates and with the wide range of substances now available this control has become increasingly important

Pre-operative nutritional requirements

Many thoracic patients apart from those with obstinate lesions of the oesophagus are badly nourished often as the result of chronic sepsis and many are in a negative nitrogen balance phase with the characteristic features of hypoproteinaemia The measures adopted for the correct nutrition of surgical patients are discussed in Chapter 5

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CHAPTER 4

OPERATIVE TECHNIQUE

ANAESTHETIC CONSIDERATIONS

The study of anaesthesia has established itself as a branch of medicine in the hands of specialists, who rightly exercise their own judgement in the choice of anaesthetic agents and the method of their administration their close collaboration with the surgeons has removed the major dangers of operating across the open pleura and this has been a major advance of the last twenty-five years in securing safer thoracic surgery Each team naturally has its own individual technique but in most centres in Great Britain there is preference for fully controlled (artificial is a better description) respiration This control



Fig 4 1 —Patient in position for left thoracotomy and controlled respiration in progress

is obtained by the use of muscle relaxants to abolish completely muscle action, including that of the diaphragm and chest wall muscles, followed by endotracheal tube administration of oxygen and sometimes nitrous oxide (or ether if diathermy is not to be used), delivered through a closed circuit to which a carbon dioxide absorber is attached and is controlled rhythmically either by manual compression of a bag or by means of a mechanical pneumo-inflator (Fig 4 1) Natural respiration by a patient undergoing thoracotomy is accompanied by a steady deterioration because of lung collapse, paradoxical breathing with the passage of tidal air from one lung to another and violent mediastinal movements (" flap " or " flutter "), the very things which delayed the development of thoracic surgery and for the correction of which bizarre attempts such as pressure chambers were made by surgeons in the early part of the century Such sequelae as carbon dioxide retention and oxygen

lack are inevitable In some countries an attempt to meet the problem has been made by employing assisted respiration in this technique the patient is anaesthetized sufficiently deeply to depress the breathing movements at the same time the anaesthetist attempts to compress the bag of the closed circuit synchronously with the patient s own efforts at breathing The control is uncertain and irregular respiratory movements may be taking place when steadiness is required during difficult stages of the operation Physiologically, such a method is often accompanied by a high carbon dioxide level and a lower oxygen one in the blood and air passages In an attempt to produce a quiet phase the anaesthetist may have to use dangerous amounts of depressant and anaesthetic agents Controlled respiration removes the adverse effects mentioned above

Pre-operative measures and pre-medication

The anaesthetist will have taken a large part in the study of the pre-operative measures outlined in Chapter 3 for his plan of action will depend on the respiratory nutritional and psychological state of the patient particular attention will be paid to the presence or absence of sputum Today the anaesthetist dealing with deliberate planned surgery will not expect to have a patient in the theatre with large quantities of sputum still present

The physiotherapeutic care of the patient on the actual day of the operation is important when the disease is associated with sputum production It is indeed rare today to have patients brought to the theatre with conditions such as bronchiectasis lung tuberculosis or cancer to have sputum sufficient to require special techniques such as endotracheal blocking or the use of the prone position (In the last 3 000 operations on the open thorax in my own Unit only two have required such handling) I believe there is little place today for these special measures which I think are often employed unnecessarily Many leading experienced surgeons, however have taken quite an opposite view to this

In cardiac surgery especially note is taken of the pre-operative measures these may have included dehydration and digitalization and the use of sedatives in nervous apprehensive patients Such measures will have been essential especially in patients with pulmonary hypertension and pulmonary oedema as in some cases of mitral stenosis A point of great importance here is the one of posture in a moment of forgetfulness a patient with pulmonary hypertension who has been nursed to a point of safety may be laid too flat during the transfer to the operating theatre such a sudden change of posture combined with unallayed anxiety has been known to induce pulmonary oedema in a patient with mitral stenosis It is wise whenever possible for the patient to be transferred to the theatre in his own bed in the position known to be the most comfortable for him

Every team has its individual preference for certain agents the aim is to remove apprehension damp down reflexes produce a dry bronchial tree and decrease the amount of anaesthetic drug required As a general routine omnopon combined with hyoscine is useful in cardiac work, pethidine in place of omnopon has the advantage of reducing bronchial secretion in addition to its sedative action. It is important to give these agents to the patient sufficiently long enough before arrival in the theatre for their efficacy to have been established and a period of one and half hours is a useful guide

Induction and maintenance of anaesthesia

In thoracic surgery this is one of the phases of the operative procedure when danger may arise suddenly and sometimes unexpectedly it is essential therefore to have in readiness all the agents required for sudden resuscitation these include everything needed to overcome ventilatory difficulties, such as adequate suction apparatus, a bronchoscope

and a tracheotomy set The instruments for the correction of cardiac arrest will be ready and sterilized before the induction of anaesthesia for any thoracic operation

With the patient in a comfortable position, thiopentone is injected intravenously and with especial care in the patient with a delayed circulation time in such patients, the delay in action might induce the anaesthetist to give an unnecessarily large dose in the belief that the patient is tolerant to the drug Once the drug has become effective and the patient relaxes to sleep, his position can be altered if the injection has been given while he was in a propped-up position an adequate dose of relaxant is given it is during this stage of induction that laryngeal spasm may develop A cuffed endotracheal tube is then passed through a direct laryngoscope and oxygen administered through this Previous anaesthetization of the larynx by amethocaine may be employed to enable easy passage of the endotracheal tube Pethidine is frequently used to supplement the action of thiopentone, especially in cardiac cases The tendency today is to have the patient in a light phase of anaesthesia, especially in cardiac surgery

Planned hypotension

Most surgeons and anaesthetists do not think that the operative advantages outweigh the dangers of hypotension produced by ganglion blocking agents The temporary lowering of blood pressure, however, during certain phases of the operations such as division of the ductus arteriosus in older patients and the surgical correction of a coarctation of the aorta presents great advantages and I do not hesitate to use it for strictly limited periods of operative time

Anoxia during thoracic operations

The anaesthetist may have to correct or prevent any one of the four types of anoxia Anoxic patients with extensive lung disease or congenital cardiac defects may come for surgery and the whole aim is to prevent further oxygen depletion The actual administration of the anaesthetic with large quantities of oxygen delivered to a patient whose basal metabolism has been lowered by muscular relaxation may explain the improvement in colour often seen when congenital cardiac patients with pulmonic stenosis are anaesthetized, although these patients pre-operatively take up as much oxygen as the pulmonary vascular bed is capable of absorbing Patients with anoxic anoxia due to lung disease are often improved temporarily by the increased oxygen delivered during the anaesthesia, when a high proportion of oxygen not only maintains the haemoglobin saturation but allows an increase up to 2 per cent in the blood plasma as a result of the raised intra-alveolar tension

Anaemic anoxia due to blood loss during the operation is corrected by appropriate amounts of transfused blood while stagnant anoxia, which accompanies early peripheral failure because the fully oxygenated blood yields up most of its oxygen before it reaches many of the tissues due to its slow rate of flow through the capillaries, requires the procedures available for countering surgical shock Perhaps the most valuable of these is to cease operating for a short time as soon as the signs of peripheral failure are noted by surgeon or anaesthetist, so that resuscitative measures may be given a full chance without being negatived by further traumatizing surgery Nor-adrenaline is of value in raising the blood pressure if used at the right stage, but must not be used if the hypotension is due to bleeding

Histo-toxic anoxia is best prevented by the adequate pre-operative preparation of toxic patients Perhaps the biggest risk that must be taken in this respect is when radical surgical measures, often the only hope of causing reversal of the process, are being employed for the treatment of chronic lung or pleural sepsis in patients who may even have amyloid disease.

Dangers of oxygen lack

Severe hypoxaemia even for the briefest period causes damage to the tissues of the central nervous system and this may be permanent The occasional tragedy of permanent mental deterioration in children who become severely anoxaemic after obstruction to lung ventilation the result of bronchial obstruction by muco-purulent sputum during excision operations can never be forgotten Lesser degrees of post-operative violence hallucination, exaggerated mental anxiety and depression are probably the result of anoxaemia during the operation or in the immediate post-operative phase Anoxaemia during or after operations may produce serious cardiac damage and possibly the cardiac irregularities seen especially after pneumonectomy for cancer in elderly subjects are due to this *

The risks of anoxaemia during operation are best diminished by controlled respiration. It is well to remember however that the high oxygen tension in the blood supplying a respiratory centre already deeply depressed by drugs such as morphine and cyclopropane prevents the stimulus of low oxygen tension a powerful excitor of the centre from acting and under this mask of depressed respiration carbon dioxide will accumulate unless the absorbing system of soda lime is working efficiently If carbon dioxide absorption is inadequate dangerous respiratory acidosis can develop

Maintenance of an adequate airway

Bronchial secretions or bleeding from the bronchial tree are the serious complications in thoracic anaesthesia , such secretions are liable to flow from the diseased lung into the trachea or opposite lung with the patient in the classical lateral thoracotomy position or from surgical manipulations of the lung in patients with bronchiectasis carcinoma, or lung abscess To avoid this danger during thoracoplasty in pulmonary tuberculosis local an aesthesia was at one time popular because the patient retained the cough reflex

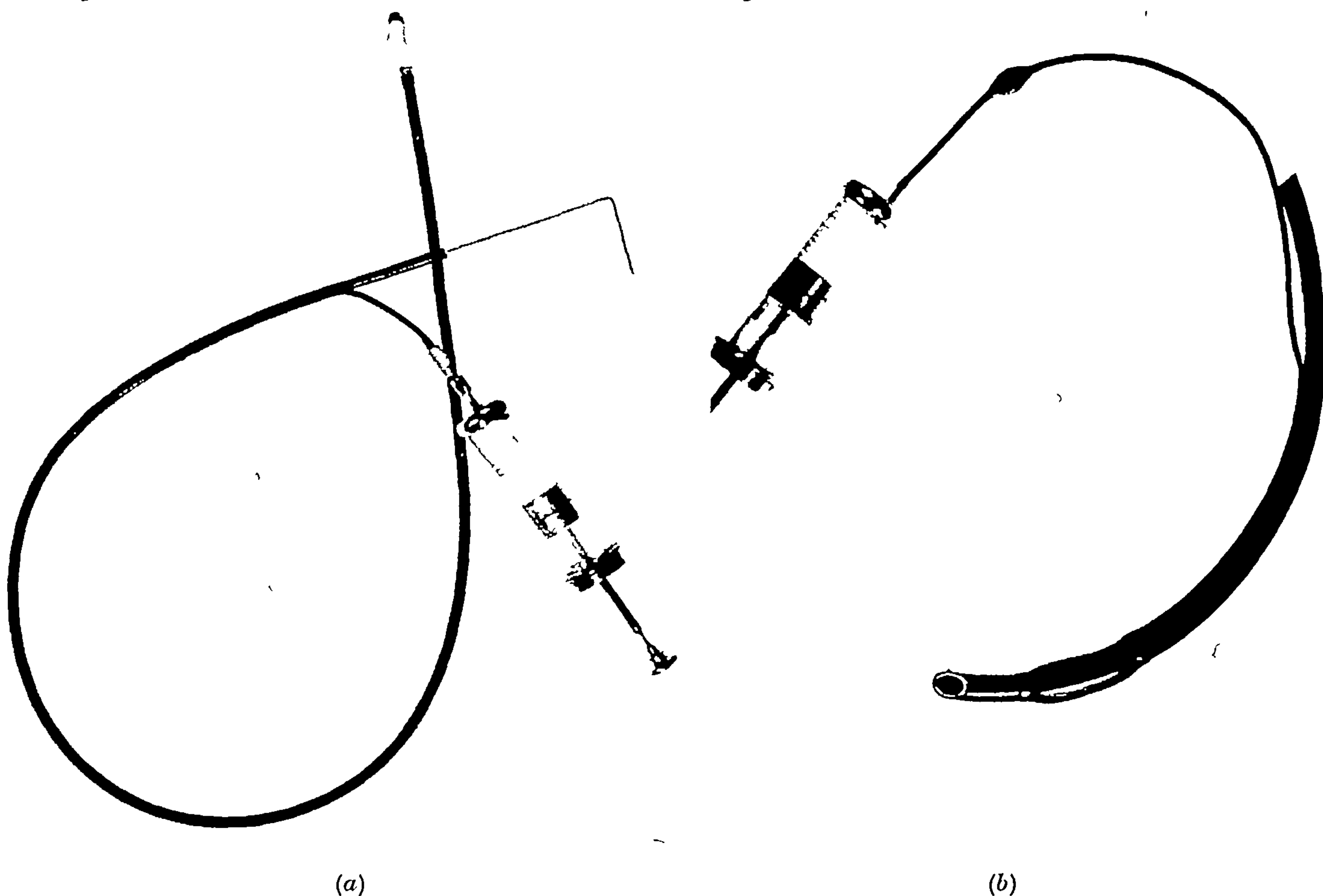
Pre-operative postural drainage is the most effective weapon still and on the day of operation must be practised thoroughly Bronchoscopic suction under local anaesthesia before the real induction of anaesthesia is started is a valuable measure in wet patients In the really wet case the area of lung from which the secretions are coming may be blocked off by occluding apparatus of which the best is Thompson s blocker and suction tube This can be placed in position under local anaesthesia

Other procedures for dealing with secretions during the operation are (1) Magill s method of intermittent suction down an endotracheal tube (2) the use of endobronchial intubation and one lung anaesthesia In this method a cuffed tube is passed into the bronchus of the sound lung so that the cuff when inflated will lie at the tracheal bifurcation and will shut off the diseased lung and its secretions When the inflated cuff lies wholly within the bronchus of the good side this method is of value in pneumonectomy *operations* and is essential for reconstructive operations on the intrathoracic trachea or a *major* bronchus (See page 280) Magill s method is to have the balloon inflated *when it lies* in the sound bronchus this allows the upper lung to collapse and yet prevents its secretions from pouring into the lower side

The Thompson blocker is used ideally in patients requiring total *pneumonectomy* for cancer bronchiectasis or tuberculosis when there is much sputum When *the Thompson* blocker is in position an intratracheal tube is introduced through which oxygen and an aesthetic agent is delivered into the normal lung *The introduction of the blocker and of*

* The state of cerebral oxygenation is delicately indicated by the use of electro-encephalography during thoracic surgery its use in surgery when an extra-corporeal circulation *is in action is essential*

the intratracheal tube are awkward manœuvres, best carried out rapidly after complete laryngeal relaxation has been obtained by muscle relaxants If the balloon slips upwards during the course of an operation severe interference with the airway to the other lung occurs and this is the most serious handicap to this method of sputum blockage



(*a*) (*b*)

FIG 4 2

(*a*) Vernon Thompson's bronchus blocker

This is of special value in total pneumonectomy or left lower lobectomy It is introduced through a bronchoscope and the terminal cuff is then inflated.

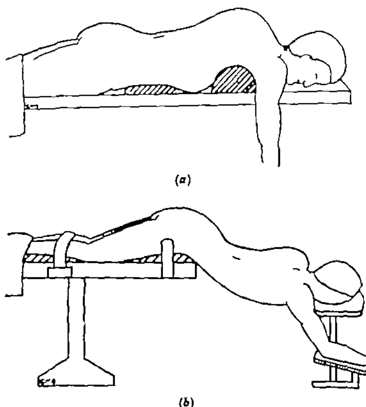
(*b*) Magill's intratracheal tube with an inflatable cuff

The use of postural drainage during thoracic operation

(*a*) *The prone position* (Holmes Sellors and Parry Brown , Overholt) This position (Fig 4 3*a*) avoids the spill over of bronchial secretions from the diseased side across the carina into the healthy bronchus and prevents displacement of the mediastinum to the sound side, which may happen during operations carried out in the classical lateral thoracotomy position The patient lies flat over carefully arranged pads which lift the upper part of the thorax and the pelvis well off the table and which ensure that the trachea and mouth are always lower than the lungs when the table is slightly tilted in the Trendelenburg position (10–15 degrees of tilt are needed) In this position secretions readily drain down a large intratracheal tube to which is connected a trap for their reception With experience the position is a reasonably comfortable one in which to operate, either for lobectomy or pneumonectomy though the incision is not so ample as in the lateral position , but if the patient is arranged in such a way that the side of the thorax to be opened is a little over the

dge of the table or there is a gap between the end of the table and the head piece (Over olt) the incision can be quite extensive (Fig 4 3b) The prone position is of great value in perations on subjects with copious sputum

(b) *The lateral position with a Trendelenburg tilt* In this position the tilt of the table the Trendelenburg position for 30–40 degrees allows secretions to trickle down a large tratracheal tube through which intermittent suction is also used The position is not effective as the face downward position but has the advantage that it allows the surgeon use the accustomed lateral thoracotomy incision



(a)

(b)

FIG 4 3

(a) The Sellors Brown position for right thoracotomy
(b) The Overholt type of position

Special points to be watched during anaesthesia

It need hardly be said that throughout the thoracic operation an accurate measurement of the pulse rate and of the blood pressure is kept Particular attention is paid by both surgeon and anaesthetist to tachycardia which might be due to blood or fluid loss and to brachycardia which is often the first warning of possible cardiac arrest it is seen especially where there is a combination of hypercardia and hypoventilation The onset of either demands immediate cessation of operative procedures and full ventilation of the lungs with oxygen Cardiac arrhythmia and irritability may accompany actual manipulation of the heart or a light degree of anaesthesia and both are aggravated by hypoxia Ventricular extra-systoles may presage ventricular fibrillation or cardiac arrest *

* *Pre-operative digitalization is the best* method of preventing cardiac irritability the use of procaine given locally or parenterally has been abandoned the drug is not effective and has its own peculiar dangers when given intravenously These are the production of circulatory collapse from myocardial depression and peripheral vaso-dilatation when large doses are given.

The chief measures adopted to overcome such abnormal cardiac movements are cessation of surgery, adequate oxygenation and careful attention to the efficacy of the carbon dioxide absorber

Adjustments at the close of the operation

As the chest wall is closed the lungs should be re-inflated after intermittent suction through the intratracheal tube or by catheter has removed all possible secretions if this is omitted the re-inflation of the lung by the increased pressure in the re-breathing bag may drive plugs of mucus deep into the bronchial tree where they may be inaccessible to subsequent suction If intercostal drainage is being employed the spigot is not placed in the end of the tube until the lungs have been fully re-inflated if drainage is not to be used at the close of the operation, the patient is turned quietly on to the back, a bronchoscope is passed and the bronchial tree on both sides is sucked clear, an artificial pneumothorax apparatus is then used to take off all the remaining intrapleural air An immediate radiograph is of the greatest value in demonstrating the actual intrapleural and pulmonary states

After respiratory equilibrium has been restored an oxygen face piece should be applied and oxygen continued while the conscious patient goes back to the ward on his bed, where he will be placed in an oxygen tent if the indication for oxygen therapy exists

If there is no post-operative recovery room adjacent to the theatre, the patient should not be returned to the ward unless consciousness and the cough reflex have returned If consciousness is not regained, chief attention must be paid to maintain efficient, persistent ventilation of the lung by means of a pressure on the bag attached to the circuit or by the use of a pulmoflater and the adequate absorption of carbon dioxide occasionally these measures may have to be continued for several hours and under no circumstances must they be stopped while the pulse persists The failure to regain consciousness may be due to carbon dioxide retention in a patient with a respiratory centre poisoned by an excess of depressant drugs or because too much relaxant has been used

If there is any suggestion that the return of spontaneous respiration is being delayed because of the action of curare or other relaxants, prostigmine is given but not until the effect of atropine has been noted as being effective

Circulatory arrest and its resuscitation

The increasing number and widening range of cardio-vascular operations has greatly increased interest in this subject Yet we have known for a considerable time that cardiac arrest may follow any surgical procedure, however minor, and any anaesthetic, even local We are also well aware that it is a treatable condition in the early stages, with full recovery of the patient in most instances Speed is the keynote of success, so that all surgeons and anaesthetists should be familiar with, and always have available, the necessary instruments and drugs for cardiac resuscitation

Sudden acute circulatory failure may result from

(*a*) Asystole or arrest of the ventricles
(*b*) Ventricular fibrillation
(*c*) Complete obstruction of the pulmonary artery, e g embolism
(*d*) Sudden massive haemorrhage, e g ruptured aorta

The first two of these causes are of overwhelming importance and aetiologically they may be considered as one, but their treatment, while similar, does vary in certain important respects

Precipitating factors in acute cardiac failure

The heart, with its high metabolic rate and its specialized tissue such as its conducting system is extremely susceptible to environmental change even in the healthy state Disease therefore can reduce still further the narrow margin of safety which cardiac physiology permits as can the effects of superimposed burdens as

Metabolic factors Anoxia accumulation of carbon dioxide lactic acid and changes in hydrogen ion concentration calcium/potassium imbalance

Chemical factors Adrenalin in excess, drugs in toxic doses e g digitalis quinidine diodone anaesthetic agents

Mechanical factors Operative procedures on the heart especially on the ventricles, cardiac catheterization

Electrical Stimuli

Reflex via vagus e g resulting from intubation of the respiratory or the alimentary tracts

Hypoxia

Myocardial hypoxia is undoubtedly the most important single factor and is of course, almost invariably accompanied by other disturbing influences such as accumulating meta bolites or acidosis The two most important individual causes of hypoxia are therefore notable —

(1) Hypoventilation by the anaesthetist during operations often with ventilatory pauses for suction and the manipulation of tubes The resulting accumulation of meta bolites is almost invariably followed by a period of hyperventilation and an inevitable rapid change in pH conditions which may give rise to ventricular fibrillation

(2) Haemorrhage—the heart being especially sensitive to rapid blood loss hypotension and the fall in coronary perfusion pressure which follows

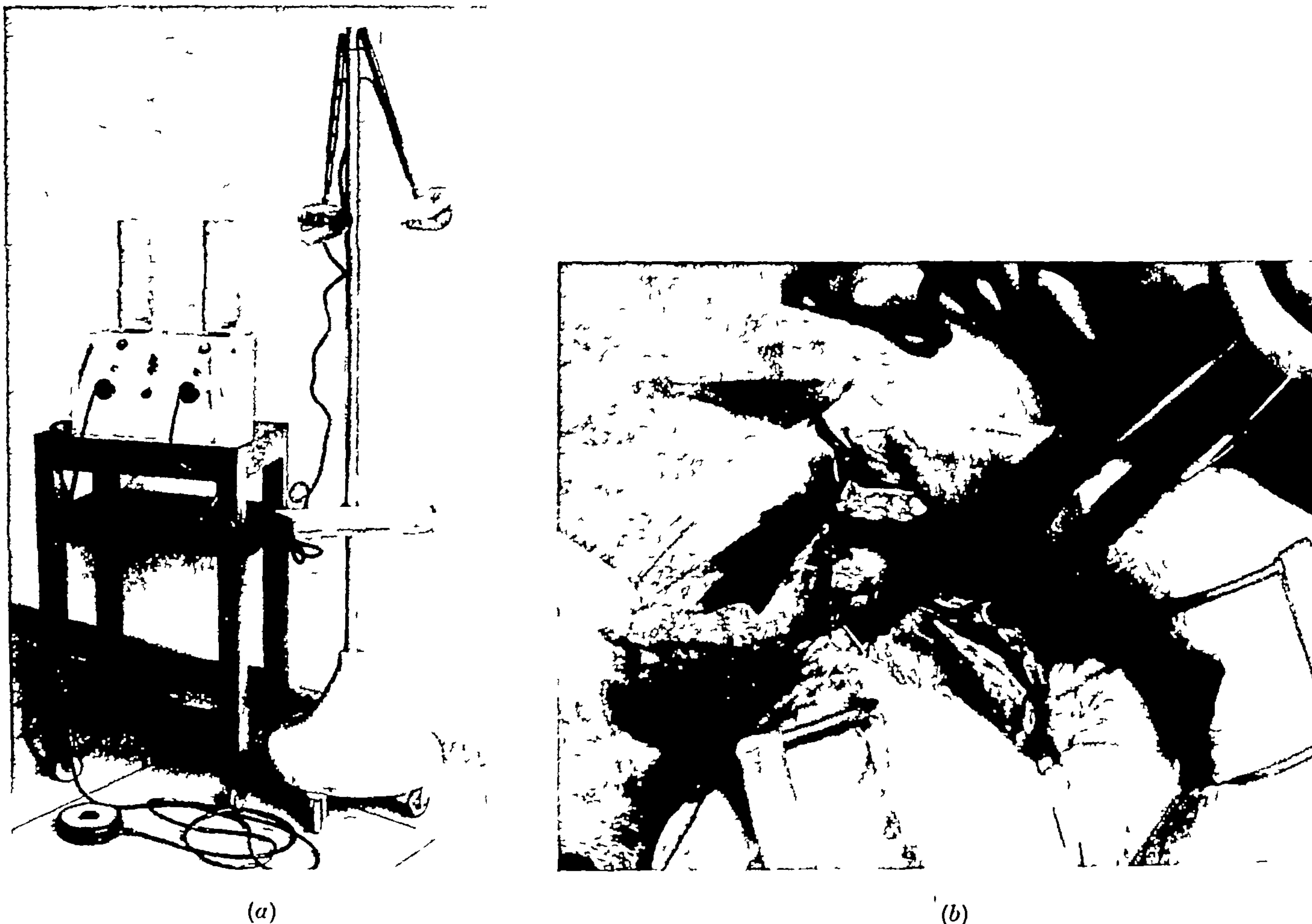
The diagnosis and treatment of acute heart failure

Accumulating evidence suggests that the vigorously pulsating heart never stops sud denly so that recognition of the early signs of cardiac asphyxia listed below become of paramount importance

(i) Sudden slowing of the pulse rate with a rise in blood pressure (Marey s law) followed usually in a few seconds by (ii) a progressive weakening of the heart with tachycardia and a falling blood pressure again usually within a few seconds to a state of (iii) ventricular fibrillation and/or asystole

With the thorax open the surgeon is well placed to note any change in the heart s work whenever there is any suspicion that the heart s action is altering the anaesthetist should be informed at once Usually a few minutes respite from active surgical movements and the full rhythmic ventilation of the lungs will rapidly restore the position If there is no cause of hypotension such as bleeding nor adrenalin run in through an intra venous drip will usually restore the blood pressure at once If there is any suspicion that cardiac arrest is imminent immediate steps are taken It is assumed that before any intra thoracic operation is started certain equipment and drugs must be available Amongst these must be mentioned endotracheal tubes appropriate connections oxygen and a carbon dioxide absorber It may seem pedantic to state this but certain procedures such as bronchoscopy angiocardiography and cardiac catheterization are still

occasionally performed without the means available for rapid endotracheal intubation followed by oxygen insufflation On a separate tray syringes, needles, adrenalin (1 in 10,000), calcium chloride (doses of 4 c c of a 2 per cent solution) and atropine are in a state ready for immediate use, the sterile cardiac defibrillator (110 V–300 V, 60 cycles, 2–5 amps) and its electrical equipment are close at hand (Fig 4 4)



(a) (b)

Fig 4 4

(a) A cardiac defibrillator
(b) The electrodes in place preparatory to defibrillation

If the blood pressure suddenly falls so that the pulse disappears in a closed chest operation, then immediate thoracotomy is imperative

Action to be taken when the heart stops

The only aim is the immediate restoration of a circulation of fully oxygenated blood, at normal temperatures three minutes is probably the maximum time available before fatal cerebral anoxia occurs This time may be less than three minutes if the circulatory arrest has been preceded by a lengthy period of general hypoxia

The principles upon which we rely are

(1) *Cardiac massage*, which was first suggested by Tuffier and Hallion in 1898, will alone restore the circulation At a rate of 50–60 effective compressions per minute it should be possible to maintain a palpable pulse with a blood pressure of 60–80 mm Hg

(2) *Pulmonary ventilation with pure oxygen* will maintain blood oxygenation An endotracheal tube is advisable but not absolutely necessary, whereas a manual compression of the re-breathing bag and a carbon dioxide absorber are vital

(3) When both of the above have been satisfactorily established then will be the time to consider the restitution of a normal co-ordinated heart beat and so conclude resuscitation

Operative procedure If the thorax is open the pericardium is immediately entered as described below If the thorax is not open rapid action is essential Asepsis is not essential A left antero lateral thoracotomy through the fourth fifth or sixth inter costal space extending from the sternum to the posterior axillary line The cartilages above and below can be divided to aid access and further exposure is gained either by an assistant or a self retaining retractor Scissors are used to make a long incision in the pericardium parallel to and in front of the phrenic nerve the whole hand is then introduced into the pericardial sac and the ventricles cupped ' The heart must be firmly squeezed so as to *empty* the ventricles Counter pressure may be necessary using the other hand, depending on the size of the heart In the meantime the anaesthetist will have established pulmonary ventilation and lowered the head of the patient By now the operator should have become aware of

(*a*) The exact cause of the failure i e either ventricular fibrillation or asystole

(*b*) The tonus of the heart muscle

Almost inevitably at first the tone will be poor If it rapidly begins to improve with the restoration of a coronary circulation it is an excellent prognostic sign that soon the heart will resume spontaneous co-ordinated beating even if the cause of the arrest is ventricular fibrillation and not asystole

If tone fails to return after massage for a few minutes an intracardiac injection of adrenalin 5–10 c c of 1/10 000 is recommended even with ventricular fibrillation $CaCl_2$ is also a useful drug in restoring tone and 5 c c of a 2 per cent solution should be used if little or no response follows the adrenalin injection

With good tone only persistent fibrillation will thwart the return of the normal beat and this should be treated by the electric defibrillator (see page 72) Large electrodes are necessary to prevent burning of the myocardium they are placed on opposite sides of the ventricles (Fig 4 4 (*b*)) Single repeated or a series of shocks may be neces sary Drugs recommended for ventricular fibrillation include procaine 5 per cent solution and potassium chloride 1 95 per cent solution If the latter is successful in abolishing fibrillation calcium must be injected after it to restore tone and the normal rhythm Swan *et al* (1053) have used potassium in this way with success in dogs

Throughout it is emphasized that an adequate circulation must be maintained by massage the only possible excuse for temporarily abolishing this procedure being to correct rapidly a cardiac abnormality such as severe aortic or mitral stenosis that is in itself prevent-ing recovery because of its gross embarrassment to the circulation

For how long should cardiac massage be maintained ? This is quite impossible to state Milstein and Brock (1954) reviewed 30 cases of ventricular fibrillation occurring during cardiac surgery with successful defibrillation in 20 and with 0 complete recoveries Successful restoration of the heart beat in one case took 55 minutes and was followed by full recovery of consciousness It must be remembered too that these patients were all suffering from very severe cardiac lesions.

In addition the rapid *restoration of the blood volume* is necessary after a severe haemor rhage Undoubtedly this is best accomplished by means of an intra arterial or better still intra aortic transfusion of oxygenated blood as recommended by Johnson and Kirby (1949) This is best done by an assistant using either a manual rotary pump or simply by the more easily available intravenous apparatus using positive pressure by attaching a rubber bellows to the bottle Great care must be taken to avoid air embolism While

this is proceeding, it is advantageous temporarily to clamp off the aorta 5–10 inches below the origin of the left subclavian artery to raise the blood pressure and improve the blood flow to the coronary and cerebral arteries A Crafoord or Potts clamp is suitable for this temporary occlusion

In conclusion, it should be emphasized that factors leading to acute cardiac arrest are preventable in most cases

OPERATIVE PROCEDURES

The great range of operative approaches cannot be systematized, the pathological processes awaiting surgical correction or assistance often require unique and individually planned surgical approaches The thoracic disease or symptoms may require an operative procedure that is performed in another region altogether, e g the use of a collar neck incision for a thoracic goitre causing dyspnoea or dysphagia, or the performance of an operation on the phrenic nerve for pulmonary tuberculosis In some operations the neck and the thorax may require approach through one or two incisions, or the thorax and abdomen may both require wide simultaneous exposure, usually through one large incision But many thoracic operations have standard patterns and it is to these that reference is now made

The approaches may be extra- or intrapleural operations, they may or may not require a rib resection Many major thoracotomies today are being done through an intercostal incision

Rib resection

The actual exposure of the rib to be resected may be by an incision dividing the overlying skin and muscles made along the line of the rib, or across its direction For a large thoracotomy the incision will more usually follow the line of the rib but in the drainage of an empyema or lung abscess it is often wiser to employ a vertical incision, so that more than one rib can be exposed, which may aid in the actual selection of the rib to be removed During this preliminary stage of skin and muscle division the use of local anaesthesia along the line of the proposed incision is a great aid to haemostasis when the patient is being operated upon under local anaesthesia bleeding points are sealed off by the use of a diathermy point placed in contact with the artery forceps The rib having been fully exposed, the overlying periosteum is divided along the length of the proposed section halfway between the two borders The periosteum is then firmly scraped upwards and downwards with a sharp, preferably curved, raspatory (the types described by Tudor Edwards and Price Thomas are excellent (Fig 4 6))

In cleaning this periosteum each movement of the surgeon's hand achieves a definite separation of the membrane and there is no need for ineffectual scratching When the upper and lower borders of the ribs have been clearly defined the curved periosteal elevator will peel the membrane off the upper edge of the rib if the operator works from behind forward and keeps the elevator close to the bone edge The lower edge of the rib is cleared in exactly the opposite direction, i e from before backwards It is often easier to clear the lower edge of the rib with a Farabœuf's raspatory than with a curved one If the upper and lower edges are cleaned as described the elevator follows the direction of the external intercostal muscles, if the raspatory follows the oblique direction of these muscle fibres

he elevation of the periosteum will be clean without the accompaniment of muscle tearing and troublesome bleeding

When the upper and lower ends of the ribs have been cleared meticulously a Doyen raspatory is passed round the rib displacing the few remaining fibres of the periosteum still adherent to the deep surface of the rib the Doyen should be passed at the posterior end

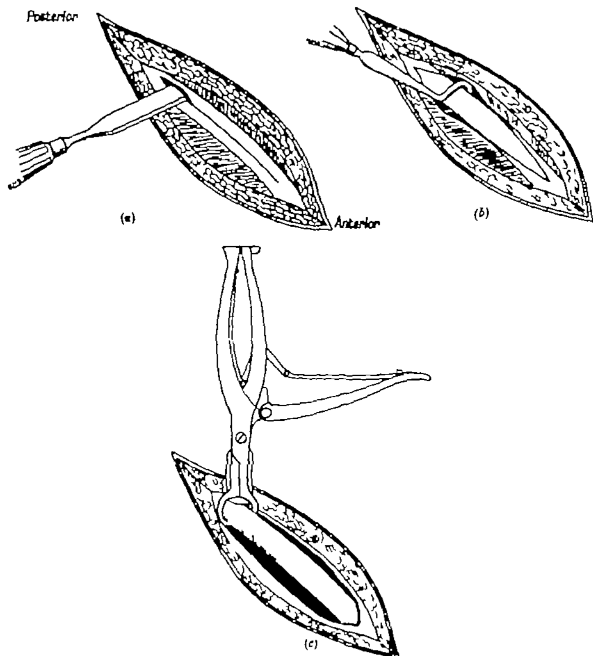
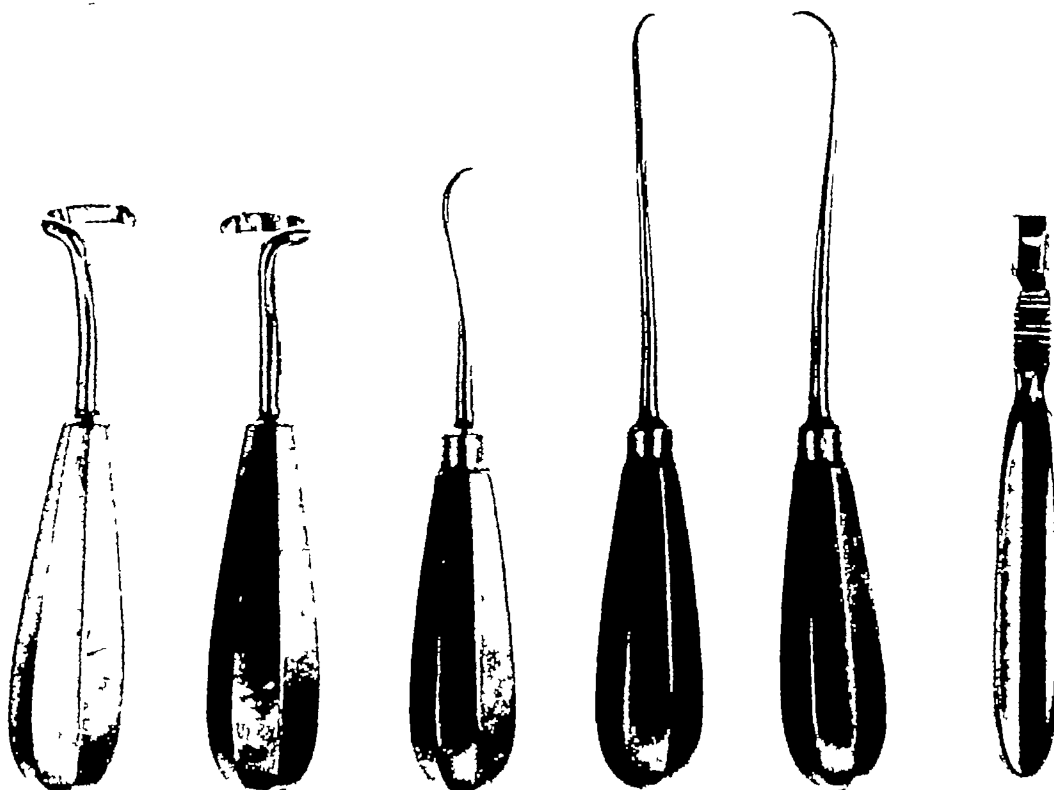


Fig 4 5 —Drawing of periosteum being scraped off the rib
( ) The start of the stripping of the periosteum.
(b) Doyen raspatory has encircled the rib and is about to detach the posterior periosteum from the bone.
( ) Tudor Ed ards costotome about to make the posterior section of the cleared rib.

of the exposed area of rib Before it is made to encircle the rib the curved elevator is cautiously edged into the posterior part of the parietal envelope care being taken to work close to the bone The Doyen raspatory is passed from above the rib to emerge at its lower border this necessitates using a right handed Doyen ' for a left-sided rib and a left-handed one for a right sided rib When the Doyen is pushed firmly towards the front end of the rib the actual pressure made by the operator s hand is upwards towards the rib



(a)



(b)

Fig. 4.6.—Instruments used in rib resection

(*a*) Left to right—left and right hand Doyen's raspatory,
three curved periosteal elevators—Tudor Edwards and Price Thomas
Farabeuf's rugine

(*b*) Left, Price Thomas angled rib shears, right, Tudor Edwards costotome

ɔh is lifted off the posterior sheath of the periosteum As the rib is cleared the periosteum away carrying in its sheath the intercostal vessels and nerves

Bleeding during these manœuvres is slight It is impracticable to pick up each small el that is divided the bleeding is best checked by the rapidity of each step because it es as soon as the rib has been divided During the actual separation of the periosteum ı the bone many small lateral branches of the intercostal vessels are torn

The rib is sectioned by one of the many effective costotomes the Tudor Edwards model ıg popular In the division of the back end of a rib during thoracoplasty a rib shears is 'erred, if the bone is to be divided through its neck Alternatively the rib can be cut r its angle and the distal part disarticulated so that the head and neck are removed rely if the operation is part of a thoracoplasty

Major Thoracotomy

(1) Posterolateral thoracotomy The approach to the superior mediastinum for ːumonectomy or upper lobectomy for closure of the ductus arteriosus for Blalock s ıration of subclavian pulmonary anastomosis and other conditions will be through the a of the fourth and fifth ribs whereas for lower lobectomy or thoraco laparotomy a lower ıce will be selected

Most surgeons prefer an intercostal incision to one through the posterior bed of a ected rib because such an approach leaves a chest more stable post-operatively and ɔbably diminishes the amount of intercostal pain For many operations there is no ɜd to divide a rib posteriorly but where a fuller spread of the ribs is required this step ı be added Typical of the operations that can be readily performed through a simple sterolateral intercostal incision are lobectomy or segmental resection especially in ıldren mitral valvotomy interruption of the ductus arteriosus Blalock s subclavian lmonary anastomosis the repair of hiatus hernia or cardiomyotomy for cardiospasm The nplest method is to clear the periosteum from the upper surface of the lower rib and to ter the pleura by an incision through the periosteal bed For pneumonectomy in adults rib resection provides a better and wider exposure as it does for thoraco laparotomy the treatment of oesophageal and gastric conditions requiring a wide opening of both vities

In operations for coarctation of the aorta a rib is resected as an intercostal incision would vide large vessels that have developed in the process of the development of a large collateral rculation Anterior thoracic approaches as for the performance of valvotomy for pulmonic enosis or for the relief of aortic stenosis through the left ventricle employ an intercostal cision associated with division of one or more costal cartilages Bilateral anterior thoraco ɔmy with transverse division of the sternum is employed for open intracardiac operations ee page 405)

The incision Whether the posterolateral thoracotomy be high or low the incision ɔmmences at the outer border of the erector spinae muscle about 3 cm from the vertebral ɔines and curved forward to the nipple line or further the anterior extension beyond this ne will usually only be required for such incisions as thoraco laparotomy *for exposure of* ıe oesophagus stomach spleen or in a right-sided operation for the performance of a orto-caval anastomosis

The line of the incision should be more oblique in the thin sloping chest of tall thin atients in the broad thick chest there are advantages in a more transverse *incision*

because the ribs run in a more horizontal direction As soon as the skin and subcuta fat have been freely divided and haemostasis effected, skin towels are applied.

Division or reflection of muscles The latissimus dorsi and serratus anterior mu are large Most surgeons divide them freely and disability is avoided if careful sutu used in the closure, but the surgical objections to such a wide division can be m reflecting the serratus with only a small division of its anterior fibres If the m is divided the auscultatory triangle should be opened and the muscle lifted up betwee fingers of the assistant and those of the surgeon The muscle can then be compressed d its division and the vessels which stand out clearly can be picked up in artery force the incision proceeds The use of the diathermy knife for the muscle incision saves i bleeding The lower part of the trapezius muscle is dealt with in the same way, the of this muscle are not encountered in the lower major thoracotomy If the thoraco is to be a high one the rhomboid muscles will require partial division



FIG 4 7—The Price Thomas rib spreader in place and the ribs slightly retracted Note that the anaesthetist maintains lung aeration

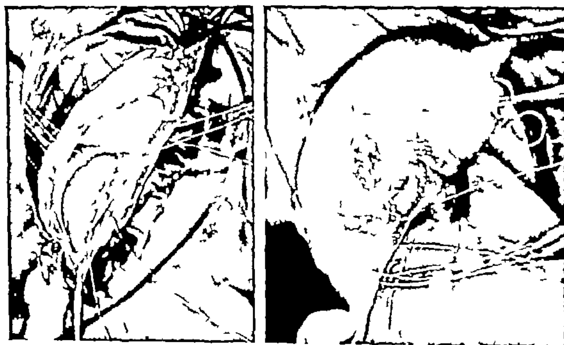
If the thoracotomy is to be by intercostal incision only, the periosteum of the l rib is cleared from its upper surface the ribs are then separated by two double ho retractors and the pleural cavity opened through the periosteal bed The incision is ca forward to the costochondral junction in front and to the transverse process behind the lower end of the wound the space is divided close to the upper surface of the l ribs so that the intercostal vessels and nerves will not be injured A few small vessels require to be secured and sealed by diathermy

If rib resection is used the pleural cavity is opened by an incision through the post wall of the periosteal bed Moist saline swabs are used to protect the edges of the pl incision before the rib spreader is put in place

The thoraco-laparotomy approach The patient is placed on the table in the lat position A long oblique incision starting from the angle of the seventh rib runs forw across the costal margin and over the mid-abdominal line to reach the outer edge of the r rectus muscle (this extensive thoraco-laparotomy is only required for operations such as t gastrectomy and for less extensive procedures the incision stops at the right borde

the left rectus muscle) The incision is deepened to the muscular plane and the muscles are divided by the cutting diathermy point The periosteum of the eighth rib is cleared and the rib with its attached costal cartilage is excised the incision is then carried across the costal margin and the abdomen is freely opened in young patients resection of the ribs is not necessary the pleural cavity being entered through the periosteal bed as described on page 77 with or without division of the rib near its angle The left pleural cavity is then widely opened and the *ligamentum latum pulmonis* divided to allow the lung to be displaced upwards The diaphragm is divided at right angles to the original line of incision if the operation is for carcinoma of the lower end of the oesophagus or the upper end of the stomach the diaphragmatic incision proceeds across the oesophageal hiatus fibres As the diaphragm is divided thread or silk sutures are passed through the cut edges on each side to provide complete haemostasis and to act as retractors to the cut muscle At the oesophageal hiatus large branches of the musculophrenic vessels require to be seized divided and tied Neither the costal margin nor the oesophageal hiatus requires division if a limited procedure such as splenectomy is the aim

Abdominal and thoracic cavities are now exposed at the bottom of a wide exposure and the organs of both are open to ready inspection if required the exposure is increased by the use of rib spreaders



(a) (b)

FIG 4 8—Transdiaphragmatic splenectomy

(a) The incision along the line of the eighth left rib which has been excised, is carried obliquely across the upper abdomen. The diaphragm has been split and temporarily sutured to the edges of the wound by *interrupted thread sutures* which have been left long. Beneath it is greatly enlarged spleen.

(b) The spleen has been easily delivered into the wound preparatory to its removal.

(2) Anterior thoracotomy This exposure is more cumbersome than the postero lateral one but has certain indications It provides poor access to the hilum of the lung and is not popular for operations on the lung whether these be pneumonectomy lobectomy or segmental removals It is used for direct cardiac operations such as pulmonary valvotomy or transventricular approach to the aortic valve through the left side or for operations for constrictive pericarditis a right anterior thoracotomy is used for

certain types of closure of atrial septal defects (Gross or Bailey method) and for tricuspid valvotomy Simultaneous bilateral thoracotomy with transverse section of the sternum is often used in cardiac surgery

The incision Unless a curved incision through the inframammary line is used the scar is unsightly, especially after transverse incision made above the nipple The incision favoured by Brock provides an excellent exposure and a good cosmetic result The third interspace is widely exposed through a curved incision that runs along the inframammary fold but does not curl up too high in the axilla The breast and pectoral muscles are detached completely below and swung upwards with the skin as one large flap which is then encased in moist saline pads The dissection is carried well backward so that the posterior parts of the third and fourth ribs are thoroughly exposed, this step should be carried out thoroughly The third interspace is opened after the periosteum on the upper surface of the fourth rib has been elevated followed by division of the third and fourth costal cartilages and ligation and section of the internal mammary vessels

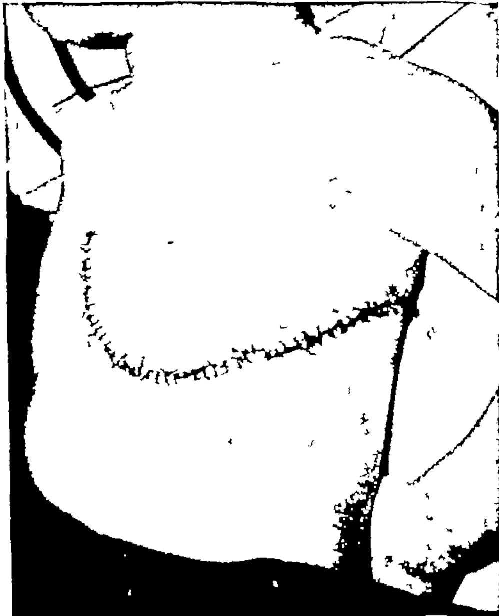


Fig 4 9 —Anterior thoracotomy incision

The wound is closed by careful suture of the intercostal space after the divided cartilages have been brought into apposition with their sternal ends by steel wire sutures The detached pectoralis and breast are re-sutured in position and the skin closed

(3) **Axillary thoracotomy.** A small, as yet unestablished, place exists for this operation, namely infrastellate ganglionectomy in the treatment of some neuro-vascular disturbances of the upper limb (Atkins, 1949) The pleural cavity is exposed by an axillary incision and the third intercostal space opened without rib division The lung is held away by suitable retraction after the space has been spread and the sympathetic cord is divided below the stellate ganglion and the posterior roots of 2, 3 and 4 thoracic nerves divided

(4) **Trans-sternal thoracotomy** This approach is almost exclusively reserved for operation on thoracic goitre, removal of the thymus and for pericardial resections in the relief of constrictive pericarditis Most thoracic goitres can be removed safely through a cervical incision but the sternum may require division quite exceptionally (see p 476) A trans-sternal approach may be required in the course of the search for parathyroid tissue in patients with osteitis fibrosa cystica Transverse division of the sternum as a continuation of an anterior thoracotomy may be needed for some intracardiac procedures (pulmonic or aortic stenosis, open cardiac surgery

The incision This commences with a small transverse cervical incision about ½ cm above the supra-sternal notch From the centre of this the main stem of the T-shaped incision divides the skin and subcutaneous fat in the mid-sternal line Normally this may extend to the level of the third or fourth costal cartilage, but occasionally the bone requires exposure and division as far as the ensiform cartilage Conversely a lower median sternotomy for the exposure of a constrictive pericarditis operation may start at the ziphisternum and proceed upwards as far as the second costal cartilage level where the bone is transected before being spread apart The length of sternal split will depend entirely on the

pathological condition that is being treated and it is sometimes advantageous to split the whole length of the bone The incision down the body of the sternum divides the periosteum

The short supra-sternal incision is deepened to expose the sterno hyoid sterno-thyroid and the sternal attachments of the sterno mastoid the upper edge of the sternum is thoroughly exposed and the supra-sternal ligament divided keeping as close to the posterior surface of the manubrium as possible the areolar tissue in the superior mediastinal space is depressed backwards largely by finger dissection and a comparatively large space is readily developed

At the proposed site of transverse section of the body of the bone the tissues are cleared by the use of a curved raspatory it is sometimes helpful to resect a small portion of costal cartilage on each side Working as close to the bone as possible the loose tissue overlying the pleural membrane on each side and the pericardium is displaced backwards and the bone then divided by a Gigli saw or bone-cutting forceps It is possible in most instances to clear the whole of the tissue behind the length of sternum to be divided by working with blunt dissection from the upper and lower ends of the T shaped incision

The sternum may be split by Lebsche s sternum-splitting knife which is driven through the bone by a series of taps with a metal mallet Alternatively it can be divided by means of Schumacher s shears or a Gigli saw passed on the director used in neuro-surgery or by a combination of Exner s bone-cutting forceps and a broad osteotome and mallet

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A wide exposure is obtained the structure most easy to damage inadvertently is the pleural membrane but this is unlikely if the preliminary blunt clearing of the back of the sternum has been thorough.

The closure When the Tuffier rib retractor has been removed the cut lower edges will approximate easily if a little support is given behind each shoulder By interrupted thread or silk sutures through the anterior periosteum and the tendinous origins of the pectoralis major muscles a firm fit is obtained Steadiness can be provided by drilling holes on each side in two places with a small brace and bit through which can be passed silver or steel wire sutures

(5) The cervico-thoracic approach Churchill of Boston has pointed out the occasional value of a combined cervico thoracic approach for the treatment of certain conditions involving the thorax and its superior outlet the incision removes all need for section of the clavicle in addition to the sternal split the exposure includes a lateral incision through an intercostal space By such an approach a wide exposition of the mediastinal structures and those at the root of the neck is obtained. It may be applied to the treatment of malignant tumours involving both thoracic and cervical territories and for the treatment of arterial or arterio-venous aneurysms of this region

(6) Bilateral simultaneous thoracotomy in cardiac surgery with division of sternum (see page 405)

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Fig 4 9 —Anterior thoracotomy incision

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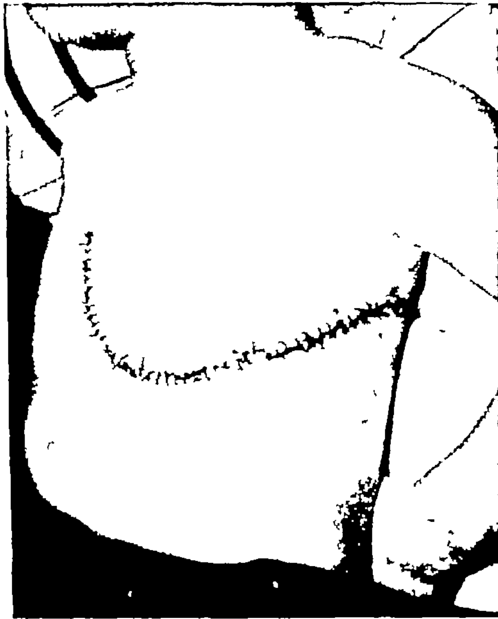


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THE SURGERY OF THE CHEST WALL

Lesions of the ribs and sternum may require surgical ablation or plastic reconstruction *Congenital anomalies* of the ribs include the presence of extra ribs usually cervical or their

absence, or the fusion of one or more ribs together Depression of the sternum (pectus excavatum) which may be congenital in origin, is now operated on more frequently than before absence or wide separation of the bone with ectopia cordis is a rare anomaly, usually fatal Brock has corrected this severe defect successfully Tuberculous conditions of the chest wall are considered on page 249

Funnel chest (pectus excavatum)

In this congenital condition the lower part of the sternum is depressed inwards, and the depression rarely involves the manubrium The cartilages attached to the sternum are longer than usual and are acutely angulated at their junction with the ribs proper and with their sternal attachment In severe degrees of the deformity the lower end of the sternum is in contact with the vertebral column, the heart being displaced completely into the left side of the chest and altered in shape

The etiology of the condition remains obscure, it may be familial The assumption that the whole deformity is started by the contractions of a shortened diaphragmatic attachment to the lower end of the sternum associated with a tense short substernal ligament is hard to believe Sweet (1950) favours the view that the sternum is depressed by the powerful posterior thrust of the deeply incurved costal cartilages Whatever the etiology, it is clear that division of the substernal ligament and of the diaphragmatic attachments does little to improve the deformity

The indications for surgical correction are for cosmetic reasons or in the presence of cardio-respiratory symptoms, dyspnoea and cyanosis may develop from mechanical distortion of the heart and a decrease in lung ventilation The operation is a considerable one but Chin (1957) has shown that relief of respiratory symptoms follows

Chin (1957) in describing his experience of 54 operations finds that the patients have three types of deformity

(1) This is the localized type in which the costal cartilages are acutely angulated well within the nipple line there is a pond-like deformity in the sternum

(2) The more diffuse type (Fig 4 11) the costal cartilages are angulated far more laterally than in type 1 and the cartilages from the second to the seventh rib are involved

(3) This is the asymmetrical, unilateral type the sternum is tilted, always to the left There is usually a groove along the left sixth interspace Chin has excellent cosmetic results in operations on types 1 and 3 and is careful to indicate that only moderate results follow operation on type 2 cases

The operation The description given is based on Sweet's modification of Lincoln Brown's (1940) operation Three main points require attention the excision of portions of costal cartilage to remove the downward thrust of these and to correct their abnormal articulation with the sternum, the elevation of the depressed portion of the sternum by means of a wedge osteotomy just below the junction of the gladiolus with the manubrium, and the re-attachment of the divided cartilages to the side of the sternum after small transverse osteotomies have been performed on the ribs to correct their inward curving

The operation is carried out under general intratracheal anaesthesia, as the pleural cavities may be opened accidentally The sternum is widely exposed through a long midline incision which extends from the manubrium well on to the abdomen · the pectoralis major muscle on each side is divided from its sternal and costal cartilage origins, below, the linea alba is incised and the rectus abdominus muscle cleared from the lower costal cartilages the ziphisternum is grasped in tissue forceps and the anterior mediastinum entered beneath and a space created between the sternum and the pericardium A small

-shaped portion of the sternum is removed from the anterior cortex of the bone just the site where the posterior depression starts and the depressed portion of the sternum ien be levered upwards The distorted articulations of the costal cartilages with the im are then excised and the cartilage or rib angulations are corrected by small wedge ions carried out at the site of maximum angulation. Sufficient costal cartilage is ed to allow an accurate apposition of the remaining stumps to the side of the sternal in their new correct line



Fig 4 10



Fig 4 11

4 10 —Congenital hernia through a deficient left lower chest wall associated with an abdominal hernia. This deficiency was later corrected by repair with fascia lata grafts at the age of one

Fig 4 11 —Pectus excavatum.

e patient, a woman of 48, three week after oesophagectomy for carcinoma of the mid-thoracic oesophagus. At operation the posterior of the sternum was less than one centimetre from the vertebral column and the heart was severely distorted and compressed t there o cardio-respiratory symptoms.

The sternum is fixed at the site of the osteotomy by several stainless steel sutures and cartilages fixed firmly and by a good fit to the side of the sternum by stout silk or wire res In a similar way the osteotomy sites on the ribs are steadied by suture The isternum is removed the pectoralis major on each side is sutured to the periosteum he sternum.

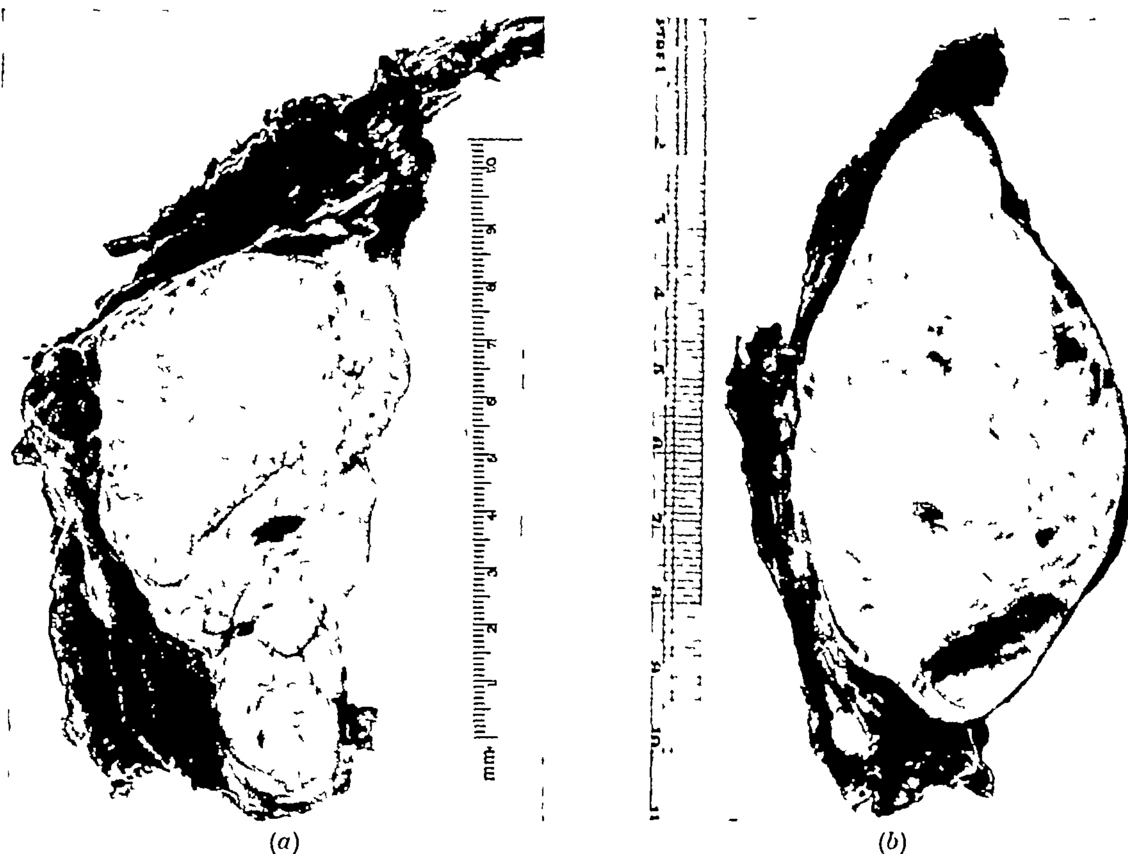
Traction on the sternum is usually necessary If there is any hint of instability a less steel wire is passed around the central portion of the gladiolus and the ends are ight out through the skin for subsequent incorporation for 10–14 days in a heavy wire supported by a moulded plaster fixed to the chest so that steady traction is maintained.

nours of the chest wall

Metastatic tumours are far commoner than primary ones but may occasionally justify sion if they are solitary and causing distress after full excision of such tumours which he case of sternal involvement may require *extensive resection closure may be effected* closure of the appropriate soft parts only but sometimes requires tantalum gauze for

reinforcement the excision of malignant sternal tumours may require division and removal of the inner ends of both clavicles

Primary rib tumours Before accepting the diagnosis that a tumour of a rib is a primary neoplasm, careful studies must be made, as differentiation has to be made of diverse conditions Barrett (1955) has listed these as *inflammation, local manifestation of general* disease, osteitis fibrosa, multiple myelomatosis, secondary metastases, cartilaginous tumours (the commonest primary one and never arising from a costal cartilage), fibrous dysplasias, lipoid granuloma, osteoclastoma, solitary *myeloma* and multiple exostoses as part of the



(a) (b)

Fig 4 12

(*a*) Tumour of rib removed by wide excision (Mr S F Stephenson) Histologically, simple chondroma (Dr C D Cruickshank)

(*b*) *Fibrosarcoma of Chest Wall*

A man of 66 complaining of pain in right chest the radiograph showed an ovoid tumour, apparently encapsulated Wide excision (Mr S F Stephenson) At operation it was invading the lung, part of which was excised Later recurrence Histology and photograph by Dr C D Cruickshank

disease of diaphysial aclasis The surgeon should always be wary of accepting unduly prominent costal cartilages as being the site of disease as unnecessary exploratory operations may be carried out

The investigation of a chest wall tumour calls for the exclusion of generalized bone disease and the search for a possible source elsewhere of a metastasis, a full radiological examination often involving other parts of the skeleton, testing of the urine to exclude Bence-Jones proteose (multiple myelomatosis) If doubt exists as to the possibility of generalized osteitis fibrosa the blood chemistry and the calcium balance must be studied The tumour that demands excision is the chondroma or the osteo-chondroma, for these have a definite tendency towards malignant degeneration These tumours often arise from the centre of the ribs, which they expand, sometimes to a huge size They may be painful and

are commonest in young adults but are seen at all ages they may have large intrathoracic prolongations and when malignant may invade lung tissue Their excision must be thorough the whole rib from the bed to the costal cartilage together with the adjacent intercostal muscles and pleura being removed as they have a tendency to local recurrence when malignant the extent of the excision may be formidable but should be attempted however difficult the reconstruction may be

The closure of such wounds can usually be achieved by using segments of nearby rib as pedicled grafts by employing soft tissue such as the breast or chest wall muscles and reinforcement with tantalum gauze If paradoxical movements are present stability of the chest wall can be achieved by the use of a moulded plaster cast

Tuberculous involvement of ribs is considered on page 240

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CHAPTER 5

POST-OPERATIVE CARE OF THE THORACIC PATIENT

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General hygiene and nutrition, combined with measures to maintain correct fluid and electrolyte balance, satisfactory haemoglobin levels and adequate lung ventilation in the pre- and post-operative phases, prevent or modify post-operative complications, not only in the thoracic surgical patient, but amongst those in all branches of surgery

Principles

After operation a rapid return to normal respiratory physiology requires that in the remaining lung parenchyma the gaseous and fluid interchange between the pulmonary blood and the atmosphere takes place in the presence of a satisfactory cardio-vascular system transporting cells and plasma well stocked with biological essentials The functional lung units must be aerated, ventilated and perfused by pulmonary blood in the presence of an alveolar membrane capable of normal diffusion

The essentials are

(1) The maintenance of an adequate breathing mixture air at normal temperature usually suffices but may have to be augmented in certain types of pulmonary failure

(2) A clear airway from the exterior to the alveoli and re-establishment of full lung volume with the pleural space occupied only by the normal partial vacuum with the parietal and visceral membranes in contact This ideal may not always be attained at once after some resection operations

(3) Encouragement of normal breathing with a chest wall and diaphragm as actively mobile as possible

Pre-operative physiotherapy, with its respiratory education and improvement in muscle elasticity and tonus, greatly eases the burden of the early post-operative days The position of the patient in bed is important In general, the supine position allows bilateral respiratory movement in three planes, enabling the diaphragm to move upwards and downwards, and the ribs to come forwards and laterally with only the posterior movements of the chest wall hampered The exaggerated sitting position embarrasses diaphragmatic movement so that the lung bases are poorly ventilated

The generalization that the supine position is the most acceptable one requires qualification Where pulmonary blood flow is embarrassed, as in early left-sided failure or in pulmonary hypertension, dyspnoea in the recumbent position is often relieved when the lung congestion is decreased by the assumption of the sitting-up position, dyspnoea after pneumonectomy for the same reason is often corrected by using the orthopnoeic position which decreases the minute volume blood flow to the remaining lung and lowers the cardiac output

Easy breathing is helped by suitable analgesic sedatives and narcotics which also reduce mental anxiety and over action of the stress adaptation mechanism

Tracheotomy may be an essential measure in maintaining an adequate airway in the post-operative period This method decreases the effort of breathing reduces the dead space air and enables bronchial secretions to be aspirated with ease (See page 540)

Maintenance of cough reflex

The restoration of normal respiratory physiology after major thoracic operations depends largely on the early and sustained return of this reflex which establishes a clear airway and encourages aeration of the lung parenchyma with normal intra alveolar tensions

Churchill (1949) emphasizes that two main functions of cough are the expulsion of mucus from the upper tracheo bronchial passages and the forcing of air into the alveoli

The bronchial musculature encircles the mouths of the alveolar ducts to form definite sphincters which trap air on expiration and only allow it to leak away gradually this mechanism maintains a relatively permanent high intra-alveolar tension Cough therefore efficiently clears the upper respiratory tract maintains alveolar tension and possibly by providing a correct pressure against the capillaries of lung parenchyma lessens the tendency to oedema development

Coughing however is not without its ill effects The ineffective cough in established atelectasis with bronchial occlusion and peripheral air absorption may serve to push exudates and infected material further into the lung parenchyma it may disseminate organisms from one area of the lung to others and in broncho-pleural fistulae leading from an empyema may produce septic aspiration effects in the other side The small half-expressed cough encountered during the performance of a lipiodol bronchography does not expel the oil entirely but often drives it into the bronchioles and alveoli

Pulmonary atelectasis

This is probably the most important complication that arises and plays the chief part in the pathological cycle that follows its onset

The anatomical distribution may be lobular segmental lobar or massive (*i e two or more lobes*) The mechanical causes may be intrinsic such as inspissated mucus in the air passages foreign bodies or kinking of a bronchus or extrinsic from the pressure of air or fluids in the pleural space on the lung or resulting from immobility collapse or paralysis of the overlying chest wall or diaphragm

The natural history of atelectasis is that early collapse is capable of spontaneous recovery the intermediate variety associated with infection or pneumonitis is probably recoverable if the bronchial tube quickly regains its patency and infection is controlled but the late irrecoverable type may lead to lung abscess or bronchiectasis

The two main theories of bronchial obstruction and of reflex nervous mechanism were unified in a masterly contribution by Coryllos (1930) who believed bronchial obstruction to be the determining cause of the collapse

Lindskog and van Allen (1930) showed that this is not quite the entire story as lobular bronchial obstruction can be compensated by collateral respiration or aeration from other unobstructed lobules This is usually impossible at the lobar levels Obstructive collapse may follow lobular bronchial obstruction if combined with obstruction of the interatrial and interalveolar communication to other lobules This latter fact can happen as suggested by Churchill either by mucous debris which is aspirated or by that which is produced locally peripheral to the obstruction by the mucous secreting cells of the bronchioles

Alternatively, physiological shut-down of these communications may occur during shallow respiration and account for lobular collapse

Atelectasis may develop rapidly as the result of straining expiration against an obstruction, with valvular mechanism in the air passage that permits the exit but not the entrance of air (van Allen and Adams, 1930), or the presence in the alveoli of the easily absorbable carbon dioxide and pure oxygen without the space-occupying effect of nitrogen

Incidence Atelectasis develops in 2 per cent of all general surgical cases In thoracic surgery the highest incidence is seen after lobectomy for suppurative bronchiectasis or for tuberculosis

The post-operative state of the bronchi and bronchioles clearly plays an important role in the pathogenesis of the disease, and this justifies the use of pre-operative measures designed to counteract infection and bronchial debris

Symptoms and signs Symptoms usually arise in the first 48 post-operative hours but may be delayed for a week or rarely 10 days There may be obvious distress with dyspnoea, cyanosis and pyrexia, but in most patients the onset is insidious and undramatic with the nursing staff reporting a state of malaise with reluctance to eat or drink

Characteristically respirations rise to 30–60 per minute and are laboured and ineffective Pyrexia of 100–102° is usual and a frequent but ineffective cough adds to the picture of general distress A little tenacious viscid sputum may be expectorated Cyanosis is present for a few hours but disappears when the arterio-venous flow shuts down

The chest wall movements are poor, especially over the area of the underlying collapsed lung , because of the high intrapleural negative pressure the mediastinum is displaced to the side of atelectasis, the intercostal spaces are narrowed and the chest wall may move paradoxically The mediastinal shift may not be marked in the immediate post-operation phase and a normally placed trachea and apex beat may accompany atelectasis due to the modifying influences of intrapleural air and fluid

The stethoscope may provide useful information as to the degree to which atelectasis has progressed In the early phase of bronchial occlusion poor or absent breath sounds are the rule and vigorous treatment may lead to rapid recovery Bronchial breathing indicates consolidation, the regained bronchial patency being accompanied by oedema or frank pneumonitis in the periphery of the lobe or segment

Radiological appearances The X-ray changes usually make the diagnosis certain, if both anteroposterior and lateral views are taken Typically the lobe is opaque The mediastinum is drawn over to the collapsed side and the ribs are approximated, with the diaphragm in a raised position

Treatment of atelectasis

Prophylactic The pre-operative physiotherapy, the active co-operation of the patient in learning good respiratory movements, the control of infection and restoration of fluid and haemoglobin levels are of great value Certain patients are especially prone to post-operative collapse , these are the nervous, apprehensive individuals, particularly the thyrotoxic and the young below the age of 10 Upper respiratory sepsis, suppurative lung conditions such as bronchiectasis, lung abscess and pulmonary tuberculosis, associated with heavy sputum production, are naturally liable to cause this complication Therefore dental and rhinological attention, postural drainage and antibiotics should be utilized

Prophylactic measures during operations. The care of the patient during the induction of anaesthesia has been described elsewhere (p 65) , pre-operative bronchoscopic aspiration, blocker devices, special positions on the table, and the use of suction through

a large intratracheal tube are everyday procedures Sedation should be light and the anaesthetic itself should be accompanied throughout by adequate oxygenation of well ventilated lungs The patient should not leave the operation theatre until the cough reflex is fully re-established

Post-operative measures These begin in the theatre The bronchial tree should be sucked free of pus mucus and fluid by catheter or bronchoscopic aspiration and the intrapleural pressures adjusted to normal If the operation has been concluded by providing closed intercostal drainage the anaesthetist will have fully re-inflated the lobe or lung if the chest has been closed without drainage the intrapleural pressures should be checked by means of an artificial pneumothorax apparatus with the patient supine A radiograph should then be taken

The constant change of position obtained by rolling the patient from one side to the other at hourly intervals is valuable when an ineffectual cough with the expectoration of viscid sputum arouses the suspicion that atelectasis is developing After lobectomy lying on the unoperated side may assist the re-expansion of the residual lobe while respiratory distress after pneumonectomy is often decreased if lateral decubitus is adopted with the operated side undermost

Although both morphine and the barbiturates may minimize the effect of stimuli to the respiratory centre the use of morphia in doses of gr $\frac{1}{8}$–$\frac{1}{4}$ [8–16 mgm] at six hourly intervals is justified. Analgesia sufficient to relieve pain in the wound that otherwise would cripple the coughing mechanisms and prevent the removal of bronchial secretions is the usual practice Care should be exercised in giving repetitive doses of morphia to elderly subjects young children and debilitated patients

Unfortunately many patients particularly after thoracoplasty are sensitive to the emetic factor in morphia and in such physeptone or pethedine can be substituted

The periodic use of 5 per cent CO_2 in O_2 mixture to maintain maximum ventilation as a preventive measure against atelectasis is no longer employed even when breathing is shallow and under ventilation is obvious When bronchial occlusion is established its use is unwise because forced breathing may drive infected material deep into the bronchioles which may cause pneumonitis

The value of good physiotherapy can hardly be overstated in helping to clear partially obstructed bronchi

Expectorants are of doubtful value Ammonium carbonate in 10 gr doses hourly for six doses may help patients who are attempting to cough up viscid sputum it is difficult to proscribe the use of the various linctus mixtures which have a soothing taste and a psychological value far beyond their pharmacological efficiency

Antiseptics and antibiotics such as penicillin in the dosage of $\frac{1}{2}$–1 *megaunit in two doses* daily of slowly diffusing solutions are used routinely antibiotics of a wider range will be used when necessary

Atropine is inadvisable as its effect on the bronchial mucosa is to make secretions more tenacious thereby embarrassing the work of the cilia. Its systemic effect on the patient is disagreeable because the tachycardia and the drying effect on the mouth are combined with an excitant action on the mental processes The viscosity of the muco-purulent exudates in the bronchial tree may be reduced by the topical use of wetting agents or detergents and such enzymes as trypsin

The maintenance of a correct fluid and electrolyte balance also helps to keep bronchial secretions thin

Treatment of established atelectasis

Atelectasis falls into two distinct phases, (*a*) the early stage of bronchial obstruction and (*b*) the later stage of consolidation

(*a*) *The early stage* The raised intrapleural negative pressure, impaired percussion, the altered breath sounds and the other physical signs indicate the underlying pathology of bronchial obstruction with absorption of the air distal to the plug and atelectasis of the lobe or lobule

The re-establishment of bronchial patency at the earliest possible moment is clearly indicated After a short but thorough attempt to unblock the bronchus by physiotherapeutic measures such as rolling and postural drainage, bronchoscopy should not be delayed if success has not been achieved

Bronchoscopic aspiration is an easy and efficient method which can be done in the ward under local anaesthesia General anaesthesia would obviously delay coughing which, occurring during the procedure, expels mucus and pus from the smaller bronchi and brings it within reach of the aspirating tube passed down the bronchoscope Suction must be deliberate and thorough At the end of the procedure normal ventilation of the involved area should be obvious with the immediate return of breath sounds

Physiotherapeutic methods must follow and further bronchoscopies are done if the lobe collapses again

Alternatively the good method of Haight (1938) of overcoming bronchial occlusion by trans-tracheal catheter suction through the nose may be used Bronchoscopy, however, appears to be as easy, more efficacious and no less trying to the patient in the hands of those used to its routine both in diagnosis and treatment

(*b*) *The later stage* This stage may be looked upon fundamentally as one of recovery where the bronchi have again become patent but the alveoli remain airless owing to an accumulation of debris , rapid progress to full recovery now depends on the presence or absence of pathogenic bacteria Diagnosis is made on the presence of bronchial breathing along with the more usual signs of collapse When this stage is reached bronchoscopy is of doubtful value, reliance being placed on antibiotic and antiseptic methods against the threatening bacterial invasion

Surgical emphysema

A mild degree of surgical emphysema in the region of the wound is common and of no significance as the air is rapidly absorbed it is the result of post-operative coughing forcing any remaining intrapleural air through the wound layers If lung tissue has been incised as in lobectomy or segmental resection air may continue to bubble out into the pleura and through the pleural incision If the chest has not been drained or the intercostal tube has been removed the appearances may be alarming

Air may be driven into the lower abdomen or up into the neck and face If the intrathoracic state is satisfactory, even the worst degrees of surgical emphysema will be absorbed without any specific treatment A radiograph of the chest is essential to ensure that the remaining lobe has re-expanded If a tension pneumothorax is diagnosed by symptoms of increasing dyspnoea accompanied by tachycardia and engorgement of the neck veins with the radiographic appearances of mediastinal displacement, an intercostal needle or tube leading to an underwater sealed drainage system should be introduced at once (see Fig 23 4)

Post-operative pleural effusions

Despite the use of routine closed drainage of the pleural cavity for 48 hours post operatively the sero-sanguinous effusion still remains one of the common complications of thoracotomy These post-operative collections depend in the main on the operative trauma which involves damage to serosal surfaces and blood vessels and lymphatic channels

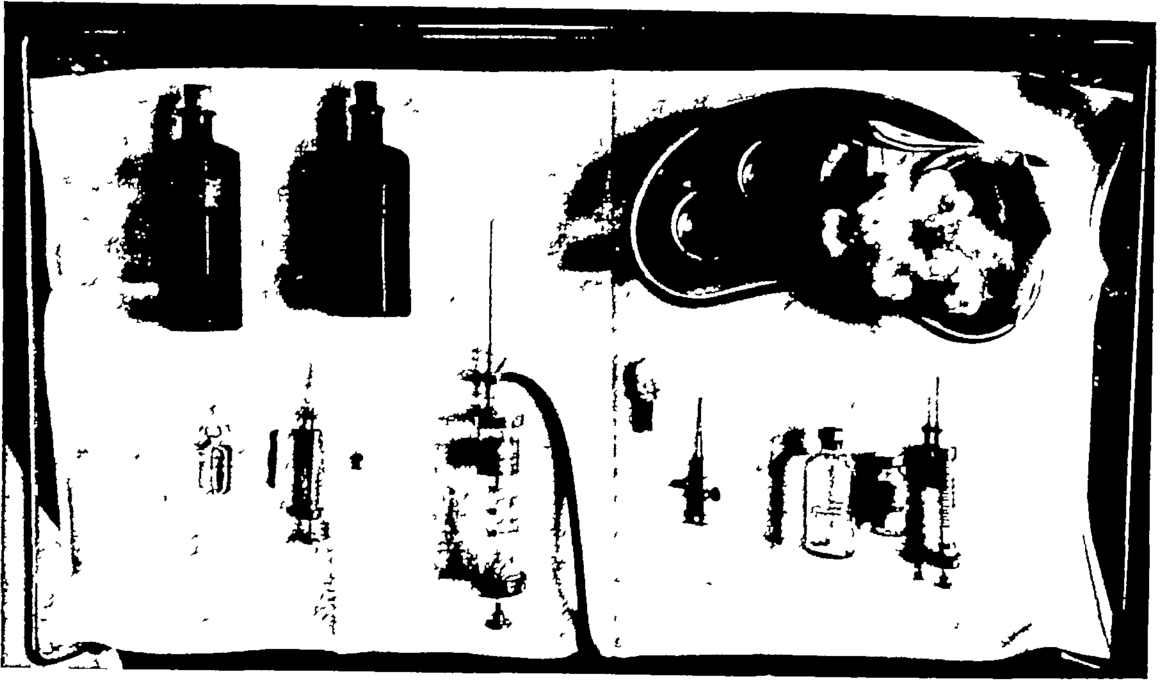


FIG 5-1 —Gross surgical emphysema after a segmental resection for bronchiectasis. In spite of the alarming appearances the lung was fully expanded and no specific treatment was given the condition subsided completely in four days.

Post-operatively a high negative intrapleural pressure especially if continuous when associated with collapse of the lung leads to an outpouring of fluid. Infection of the pleura may be followed by the classical signs of inflammation with the outpouring of inflammatory exudate Blood itself in the pleural cavity excites effusions and this underlines the importance of good aspiration technique, when reliance is being placed upon aspiration in the management of such collections

Nature of effusions In view of the underlying etiology it is clear that effusions may be serous sero sanguinous purulent or chylous Especially important is the fact that haemothorax fluid may clot and the organization of such a process may constrict the lung and limit the chest wall movements When such organization begins to take place the effusions may become loculated forming a series of complicated pockets which in turn may become infected

Sero-sanguinous effusions may clot in the absence of infection that blood will clot in the early stages is obvious to any surgeon who has opened the pleura but usually post-operative clotting rapidly becomes defibrinated probably under the influence of the cardiac and thoracic movements In the absence of infection the clots are usually fragile and quite different from the chocolate brown ones noted in the infected haemothorax (see p 540)



(a)

(b)

FIG 5 2 —Trolley as set for post-operative aspiration of pleural effusions, using Stott s artificial pneumothorax apparatus

(a) Below the antiseptic solutions and the wool swabs, etc , are placed an ampoule of local anaesthetic the file for opening it, a hypodermic syringe and needle for its injection , to the right of this is a 10 c c record syringe with two way attachment, exploring needle and rubber tubing attached a sterile test tube for the bacteriological and cytological examination of aspirated fluid, an artificial pneumothorax needle, sterile water and a tube of crystalline antibiotic together with a syringe and needle for its intrapleural injection

(b) When the exploring needle with its two way tap has reached the intrapleural effusion, withdrawal of the latter is facilitated by the use of the artificial pneumothorax apparatus as shown connected to a Winchester for the collection of fluid and air aspirated

The principle established in the war that a haemothorax should be aspirated in the very early stages should be applied with emphasis to post-thoracotomy effusions

Morbidity Most post-operative effusions are of minor importance but serious troubles can arise depending on the size nature and possible infection A large rapidly formed effusion as seen occasionally after pneumonectomy may impose a severe nutritional burden on the patient Hypotension pulmonary oedema and/or a cardiac arrhythmia may follow as a result Serious later effects depend on the pathological process of organization into fibrinous haemothorax or following infection the onset of a frank empyema

Post-operative treatment The early diagnosis of these effusions by clinical and radiological signs should lead to their immediate and complete aspiration Aspiration encourages full and rapid expansion of the lung or lobe with obliteration of the space so that clotting loculation and infection are prevented Small effusions however often resolve satisfactorily without treatment

Aspiration technique Pre-medication by omnopon and scopolamine is used The patient should be propped up in a comfortable position with pillows suitably placed frequently aspiration after transpleural operation can be carried out most satisfactorily in the axillary line Local anaesthetization of the skin and pleura of the selected intercostal space allows a large bore needle to be used without discomfort to the patient The use of a two way syringe has been found to be most satisfactory The Potain s aspirator is not in general use today Following aspiration antibiotic drugs such as penicillin or streptomycin are instilled into the space if indicated

Loculated effusions require multiple aspirations but when infected or clotted the usual principles governing the management of empyema and multiloculated effusions (see p 116) are adopted with recourse to surgical clearance These measures include rib resection and drainage or thoracotomy clot clearance and pulmonary decortication

Chylo-thorax (See page 556) This complication deserves special mention It may be due to malignant disease not necessarily primarily focused in the lung in which the lymphatics become blocked or it may be associated with trauma cases being seen in which a chylous pleural effusion follows injury not necessarily of severe magnitude If untreated, the patient loses weight shows a low white cell count particularly lymphopenia and eosinophilopenia and the correct measure is to identify and ligature the damaged duct as soon as possible

Post-operative broncho-pleural fistula

Broncho pleural fistula of the major bronchi today is rarely a problem after lung resection Better surgical technique and the antibiotic agents have greatly decreased their incidence but disease processes such as malignant tissue invasion or tuberculous infection of the bronchial stump are responsible for some It is important to differentiate between the rare fistulae of the main bronchi and those of the bronchiolar/pleural type which occasionally occur after lobectomy but more often after segmental resections

Types of bronchial fistulae The fistula may be *early* developing within the first two post-operative weeks and serving as a reminder that the techniques for bronchial closure are still not perfected Or *late* when it is heralded months or even years after resection and associated with an undramatic dormant empyema or representing a malignant necrosis after pneumonectomy for carcinoma of the lung *In this latter* group the development of an empyema may be insidious and overlooked, the emaciation and falling away of the patient being attributed to a malignant recurrence until the sudden expectoration of pus or a swelling of the chest wall discloses the presence of the empyema Such possibilities underline the

need for the constant clinical and radiological review of the post-pneumonectomy space if this has not been obliterated by a post-resection thoracoplasty

Diagnosis of post-operative broncho-pleural fistula Fistula may follow pneumonectomy or lobectomy with acute dramatic symptoms after a bout of paroxysmal coughing the patient may expectorate a considerable quantity of haemothorax fluid If the opening is small and valvular the symptoms of tension pneumothorax may be added to the picture, cyanosis, distress, tachycardia and distended neck veins being obvious The trachea and mediastinum may be displaced The other lung may be flooded, with immediate or later death from the effects of the aspiration

More usually the onset is less dramatic, persistent cough with the expectoration of small quantities of blood-stained pleural fluid, especially after changes in position, indicating that a small fistula has developed

If the fistula develops after the patient has left the hospital, usually they are ill and toxic and often with the history of continuous expectoration of purulent sputum These patients have an empyema which can be detected by radiological examination followed by a thoracentesis which reveals the pus Although most common after pneumonectomy for cancer, occasionally a late empyema follows lobectomy for bronchiectasis and tuberculosis Such a condition was common in the old days of tourniquet lobectomy, when the state was referred to as a " stump abscess " An abscess round a broncho-pleural fistula is dangerous because it may lead to severe infection, atelectasis and bronchiectasis of the remaining lobe

Treatment Prophylactic measures include good technique at the operation and the immediate post-operative re-adjustments already described After pneumonectomy high negative pressures in the early phase after operation should be prevented this requires frequent radiological examinations and the re-adjustment of pleural pressures by the aspiration of blood and air If the pneumonectomy space has been drained by an intercostal catheter this should not be allowed to drain continuously as it increases the negative pressure and removes the valuable cushion of air within the closed hemithorax Such intercostal drainage which has as its object the removal of post-operative effusions should be intermittent, the clip on the rubber tubing leading to the water-sealed bottle being relaxed at intervals and removed after 48 hours Drainage is not employed in Birmingham after pneumonectomy, the fluid and air contents being controlled by aspiration

At the close of each aspiration intrapleural antibiotics are injected into the pleural space

Fistulous development after lobectomy is rare it is seen occasionally when the remaining lobe fails to expand quickly to fill the hemithorax Its chief preventive treatment is good technique in stump closure, and measures used to obtain rapid re-expansion of the remaining lung tissue

The late development of an empyema after total lung resection could best be avoided logically by using thoracoplasty afterwards This should be done after resection for tuberculosis but most surgeons dislike its performance after the lung has been removed for cancer

The treatment of a broncho-pleural fistula depends on the mechanical and septic complications

Conservative—Drainage by intercostal catheter or needle aspiration combined with antibiotic therapy

Operative—(*a*) Immediate thoracotomy with closure of the fistula with or without drainage and with antibiotics

(*b*) Thoracoplasty, with or without drainage

The least frequent in use immediate thoracotomy is reserved for the early fistula diagnosed quickly and before infection has taken place By this means a bronchial opening due most likely to faulty technique in bronchial suture can be dealt with before purulent and fibrinous deposits around the area have made such a formal operation unlikely to succeed. The later fistula unless due to malignant necrosis of the bronchus stump is usually dealt with by thoracoplasty after the pleural space has been drained Finally treatment will be influenced according to whether the preceding operation was a pneumonectomy or a lobectomy

Before a decision is taken as to the methods to be adopted bronchoscopy is of considerable help especially in the pneumonectomy group of patients by it information can be obtained as to whether malignant recurrence is the cause Some estimate of the size of the fistula can be obtained and from time to time the cause of the alarming symptoms of cough and slight haemoptysis can be seen as a partially extruded suture which can be removed.

If a fistula has caused an empyema after pneumonectomy the aim should be to aspirate the pleural cavity to dryness if possible or to employ temporary tube drainage and proceed as soon as possible to thoracoplasty Such a thoracoplasty has better chances of closing the pleural space if employed early than if used after a long period of drainage after rib resections If the fistula has developed early in pneumonectomy cases and has been re-sutured thoracoplasty should be employed early

A small fistula occurring early after lobectomy will often demonstrate its presence by auscultatory methods and by an increase in the size of any residual pneumothorax on the radiograph the future course of the patient will depend on the state of aeration of the remaining lung tissue If this can be re-expanded fully the fistula will become sealed off Temporary intercostal drainage should be re-instituted at once and bronchoscopy done if the remaining lobe is atelectatic

Quite exceptionally there is a case for re-suture of the lobar stump where drainage bronchoscopy etc fails to re-expand the remaining lobe If neither of these methods succeed and the remaining lobe fails to re-expand a total empyema will develop which all too often requires residual lobectomy and thoracoplasty for its cure

Bronchiolar-pleural fistulae

The clinical picture of this complication follows from the observations that although the air leaks into the pleural space there is no reverse leakage of pleural fluid and resulting infection of the space is rare Its onset is immediately after the operation and it may persist for any length of time untreated

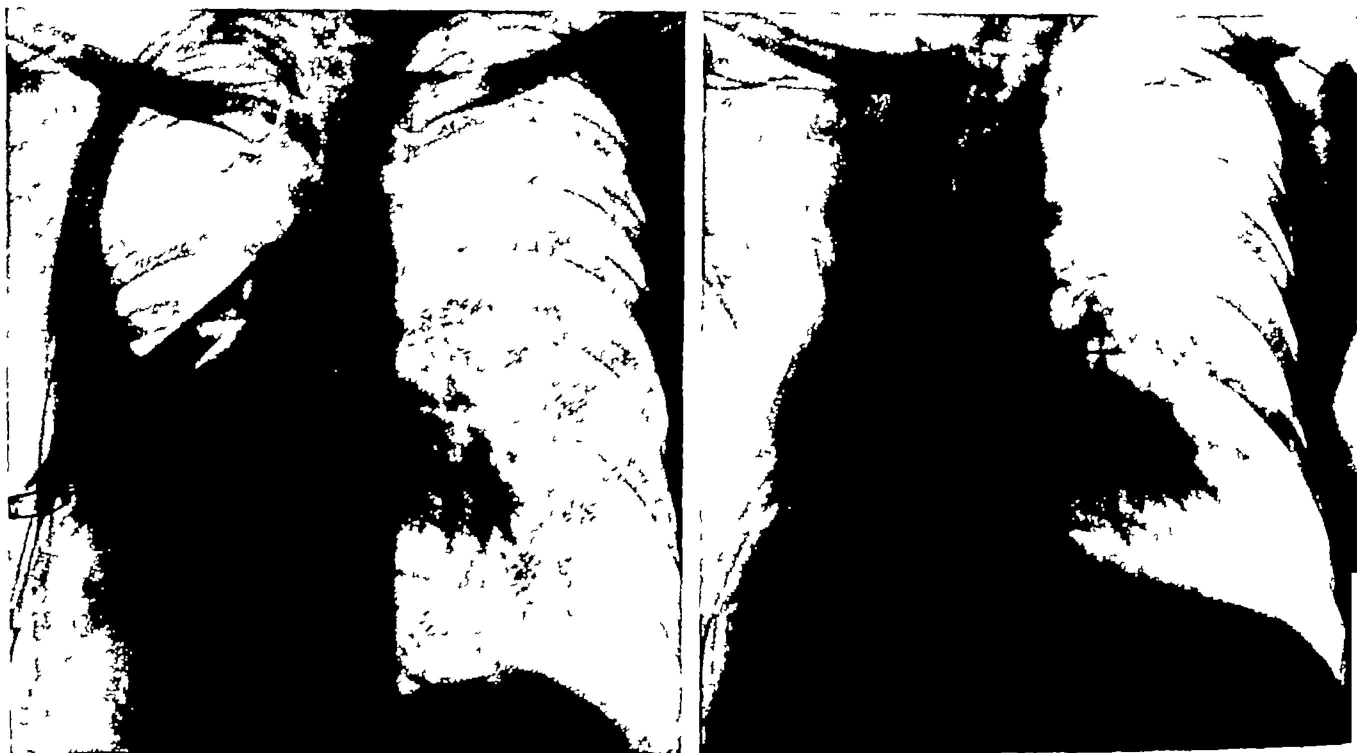
The conditions predisposing to this complication are abnormalities of the bronchial tree such as bronchiectasis and emphysema and operative failure to keep exactly to the intersegmental planes a fault that cannot always be avoided since in many tuberculous patients this plane is involved in the disease

Clinical effects These depend on the amount of air leaking and the extent of the existing pleural symphysis The patient usually suffers from a persistent and often dry cough while occasionally in the absence of effective drainage it is associated with surgical emphysema The X ray picture is one of total or of a varying degree of pneumothorax or of a residual pleural air cyst

Treatment Prophylactic Experience has shown that care should be given to pre operative assessment of the surrounding segments using bronchography and to operative technique which should be strictly intersegmental using the intersegmental veins as a guide After careful suture of all the obvious bronchiolar leaks the raw surfaces of the

lung should be approximated using multiple interrupted stitches Adequate mechanical suction drainage must be provided if necessary by using multiple motors, so that rapid full re-expansion and adherence of the lung surfaces to the chest wall takes place

Definite treatment Persistent drainage with minor leakage and where the lung remnant is well expanded, will probably be all that is necessary Rarely will a second thoracotomy be needed to close the fistulae Treatment by a space-closing thoracoplasty alone is not often recommended This subject is considered further in Chapter 10



(*a*) (*b*)

Fig 5 3

(*a*) A post-pneumonectomy empyema has been drained
(*b*) The same patient after thoracoplasty, which has obliterated the empyema space

Cardiac arrhythmias following thoracic procedures

The chest surgeon's experience of the arrhythmias has widened very considerably in recent years with the steady increase in the numbers of cardiac patients being submitted to surgery, and to such investigations as cardiac catheterization and angiocardiography While admitting that many arrhythmias are present before surgical intervention, nevertheless modifications of them or even arrhythmias *de novo* do arise in the post-operative period after major procedures in the chest such as pneumonectomy for carcinoma, in addition to cardiac operations

Fortunately, most of them are of the supra-ventricular type producing little change in function as manifest by blood pressure, heart rate changes, etc , and are often transient, yet their early and accurate diagnosis is sometimes life-saving For this reason electrocardiography is considered to be invaluable in both the wards and in the operating theatre

Massie and Valle examined 120 patients after pneumonectomy and found 11 examples of arrhythmia, 5—A F , 4—A flutter, one with extrasystoles and one with ventricular fibrillation In our experience, transient arrhythmias are much commoner than this and

may exceed 50 per cent of the total number of patients over 50 years of age submitted to pneumonectomy for carcinoma

Apart from age and intrinsic heart disease the factor which predisposes to arrhythmia is an increase in the ' irritability of the myocardium consequent on nutritional disorders such as anoxia CO_2 accumulation pH changes and potassium depletion Digitalis intoxication especially in the presence of potassium depletion also predisposes to arrhythmia

Atrial fibrillation is by far the commonest disorder yet occurrence of other atrial tachycardias such as flutter with changing atrio/ventricular block with its risk of sudden ventricular tachycardia and circulatory failure may be met

Treatment With an accurate diagnosis of the arrhythmia and in the absence of congestive failure such nutritional disorders as anoxia should be corrected by careful transfusion and oxygen therapy together with sedatives Occasionally potassium has to be given and since intravenously its administration is dangerous without strict E C G control it should be given by mouth Dosage depends on the extent of the depletion but 1 gm of KCl followed by ½ gm at 3–6 hourly intervals is usually safe, a larger dosage may be necessary in the more severe depletions

Digitalis is recommended where ventricular rates are fast and in atrial flutter in order that this irregularity will be rapidly converted to the much safer fibrillation Pre operative prophylactic digitalis is not recommended because of the increased suceptibility to arrhythmia remembering that digitalis may be given intravenously in an emergency (1 mgm as first dose followed by 0 5 mgm in 6 hours and 0 5 mgm by mouth in a further 6 hours) * Exact dosage is very much an individual matter and always great care should be taken Other drugs such as quinidine and procaine amide are of use the latter particularly in an emergency for the ventricular tachycardias

Pulmonary oedema after thoracic operations

This is perhaps the commonest cause of unexpected death after *major thoracic surgery* It is met most frequently as a result of anoxia following such procedures as pneumonectomy in the elderly and in patients with impaired respiratory function and after thoracoplasty A mitral valvotomy complicated by severe incompetence may die from pulmonary oedema

The pulmonary capillary is unique in that as it lies in relation to the alveolar apparatus it is unsupported by the usually intercellular matrix and fluid A thin film of water and electrolyte lining the inner wall of the alveolus presumably held there by surface tension, is the only remnant of the interstitial fluid found around systemic capillaries *the supporting* effect of the remainder is represented by the intra alveolar gases under tension saturated with water vapour Since gas exchange is the function of the pulmonary capillary *this* arrangement with the minimum of fluid exchange is ideal

Fluid retention is extremely important and is controlled by the balance between (*a*) the hydrostatic intracapillary pressure plus the small osmotic pressure of a possible protein content in the alveolar film and (*b*) the *osmotic* pressure of the intracapillary proteins plus the intra alveolar gas pressure

The aetiology of pulmonary oedema may therefore be due *to either of the following* alone or in a combination

1 Pulmonary hypertension with a consequent rise in the filtration pressure to a level exceeding that of the normal plasma *osmotic pressure of 25* mm *Hg*

2 A fall in the intra alveolar gas tension consequent upon poor ventilation

* This caveat does not apply to cardiac surgery where the indication for pre-operative digitalization is often present

3 A fall in plasma osmotic pressure

4 Damage to capillary permeability which, for example, may be brought about by noxious gases like phosgene, blast injuries and possibly by anoxia

Without doubt, pulmonary hypertension, especially when it arises following the interference with the venous outflow of the lung or as a result of anoxia, is the most potent cause of pulmonary oedema (Motley *et al*, 1947)

The nervous control of the pulmonary vascular tree is probably reflected in the clinical effects of anxiety, fear and pain upon patients with pulmonary hypertension, it may be sufficient to push them into oedema Faulty management of the water and electrolyte balance causing dilution of the plasma proteins with perhaps an increase in the thickness of the alveolar water film, leads to anoxia and its vicious circle association with pulmonary oedema

The treatment of pulmonary oedema after operation depends largely upon the pre-operative diagnosis of susceptible subjects, its anticipation and prevention, for example by the appropriate dehydration of patients with severe mitral stenosis For the established condition, the adoption of the orthopnoeic position, morphia and other sedatives to control pain and anxiety and oxygen, the latter being the most important of all Oxygen should be given continuously in high concentrations, in the hope that all signs of anoxia such as cyanosis will disappear, for it is only in this way that the all-important lowering of the pulmonary capillary pressure will take place

Ancillary measures like bronchoscopy or tracheotomy may help by clearing the bronchial tree of gross obstruction

Post-operative venous thrombosis

Two per cent of all surgical patients after operation show signs of deep vein thrombosis, it is estimated that approximately 1/1,000 die The potential danger to life of this complication, and the occasional occurrence of chronic post-thrombotic states such as persistent oedema or ulceration, emphasizes the need to understand this condition

It will be sufficient for us to summarize the facts related to post-operative intravascular clotting, and later to correlate them with preventive measures and the early treatment of the established condition

The aetiology may be subdivided into

(*a*) Local factors—trauma
—venous stasis
(*b*) General factors—circulatory
—toxic

Local factors Injury to the endothelial lining is an essential requirement for blood to clot in a vessel The veins most commonly involved are the deep intra-muscular ones of the calf

Venous stasis itself may result from local pressure, but more commonly it arises from a combination of factors which includes, besides pressure, the anti-gravitational position of the limb and muscular inactivity

Other local circulatory factors favourable to blood clotting quickly follow venous stasis, these include "sludging" of the blood and exaggeration of the normal laminated flow with the lightest fragments, i e the platelets, on the periphery Therefore, when and where favourable circumstances occur, as in an injured endothelial site, the platelets are more able to adhere quickly and begin the clotting process

General circulatory factors The general blood changes which also predispose to intravascular clotting are important These blood changes are part of the natural adaptation to the trauma process and include an increase in the platelet count and in the plasma fibrinogen content

These effects are at a maximum between the sixth and twelfth post-operative days

Lastly, the general effects of the illness on the patient are important, all clinicians are agreed that it is the "ill" patient who is prone to venous thrombosis These effects, many of which are amenable to treatment, include anaemia, dehydration and the excessive use of sedative drugs

Other factors are (*a*) *Bed rest and the position of the patient* Since the venous return from the lower limb normally depends upon its activity any reduction in muscular movement such as occurs with bed rest will naturally favour venous stasis This effect is exaggerated by the upright or anti gravitational position of the patient in bed

(*b*) *Respiratory movements* The diaphragm and chest wall movements are very important venous pumps Restriction of these movements often follows an operation particularly as a result of pain and often from the position of the patient in bed

However to summarize it is the *ill* patient who suffers most frequently and who may ultimately die from a fatal pulmonary embolus Therefore adequate preparation of the patient good surgery and careful post-operative management including physiotherapy are important prophylactic measures Special post-operative measures such as early ambulation have been accepted by all ambulation however is not sitting about in a chair which obstructs the venous return far more than lying in bed with the foot raised and with frequent encouragement to respiratory and leg muscle activity The use of the bed cradle minimizes local vein trauma and encourages leg muscle activity

Before proceeding to a discussion of the treatment of an established thrombosis a diagnosis and particularly a very early diagnosis must be made The lower limbs in ill patients should be examined twice a day with the following symptoms and signs in mind

The symptoms and signs of deep vein thrombosis may be —

(*a*) *Overt or obvious*—Local pain and tenderness of the muscles of the calf and the soles of the feet are important pointers and may be accompanied by evidence of deep venous obstruction such as peripheral cyanosis, dilated superficial veins and/or oedema often there is slight pyrexia Pulmonary embolism causes dyspnoea chest pain cough and haemoptysis Or

(*b*) *Insidious*—The general condition of the patient shows a gradual deterioration with unexplained temperature

Only on direct examination is local tenderness and rigidity of calf muscles detected on examin tion with Homan s sign positive Pulmonary embolism may be silent and only one third of fatal pulmonary emboli have a warning embolus

Treatment of the established condition The anti coagulants are the mainstay of our present day treatment and rarely need such adjuncts as deep vein ligature as advocated by Allen (1947)

Heparin which may be administered either intravenously or intramuscularly is an anti thromboplastin it acts rapidly but its effect is of short duration whereas the coumarol type of antiprothrombin drugs which can be administered by mouth are the reverse that is they are slow to bring about their effect but are long acting and often show a tendency to accumulation

Nowadays both are utilized being given together immediately the diagnosis has been made The heparin raises the clotting time at once to antithrombotic levels while the coumarols becoming effective after 24 hours enable the heparin to be stopped. The dosage of heparin is controlled by four hourly examination of the blood clotting time while in the case of the coumarols at least daily measurement of the prothrombin and factor 7 clotting times are necessary Strict laboratory control is essential.

Adjuvants to anti-coagulant therapy Temporary local rest of the affected leg with elevation to encourage the venous return by gravity is advised until a satisfactory blood level of anti coagulation has been established At this stage whenever possible full muscular activity includ ing ambulation should begin Anti coagulant therapy continues until all the local signs and symptoms have disappeared or for at least three weeks after the onset of the thrombosis

Elastic pressure bandages are used in patients with persistent oedema

NUTRITION OF THE SURGICAL PATIENT

Many patients under the care of the thoracic surgeon show malnutrition the chronic solid type of depletion being especially common It follows such disorders as obstructive states of the upper alimentary tract severe infections neoplastic disease and anoxia Anoxia is common and may be due to any of the classic causes

Before proceeding to consider the management and the post-operative nutritional requirements of chest patients, it is important to remember that driven by endocrine stimulus their response to trauma follows a well-regulated pattern We have to recognize this physiological response as a normal process that must not be interfered with, other than by controlling as far as possible the overall stimulus by reducing to a minimum operation trauma, avoiding severe blood losses, controlling pain and fear and with the elimination of ether anaesthesia

The immediate post-operation or catabolic phase is characterized by a negative N and K balance due to the compulsory breakdown of the body cells Active retention of Na and H_2O coincides with this phase

All the basic food materials during this period are provided endogenously so that no external help other than free H_2O, sufficient to cover obligatory losses, is required Misguided aid thrust upon the normal patient during this period will not only be wasted but may embarrass the natural adaptation processes This phase usually lasts from 3 to 5 days, it may be " short " and " mild " in patients after minor trauma and after minor operations, or in those whose nutritional state pre-operatively was poor, the " predepleted response " of Moore *et al* (1952) This type of response might be regarded as fortunate for subjects ill equipped to withstand a long catabolic phase, were it not that a " moderately severe response " in fit patients is so obviously the normal response when considered from such points of view as rate of recovery, sound wound healing and complication rate

The convalescent or anabolic phase follows immediately and is characterized by active cell rebuilding as evidenced by a positive N and K balance A water and salt diuresis accompany the onset of this stage It is essentially for recovery and should be provided for clinically by an ample supply of calories and nitrogen together with all other protorplasmic rebuilding materials

The nutritional aims

1 *To bring to the operating table patients in balance for all food materials* In many instances this is, of course, quite impossible but, even so, a normal H_2O, electrolyte, protein and red blood cell volume should always be insisted upon

A period for pre-operative " solid " nutritional rehabilitation is recommended in all suitable depleted patients Providing that sufficient basic food materials are given and activity is encouraged, a satisfactory positive protein and calorie balance may be maintained, leading to an accumulation of mobile reserves of muscle and fat, possibly later to be used for compulsory post-operative catabolism

2 *To provide free water to cover obligatory losses during an uncomplicated catabolic phase*, preferably by mouth in amounts around 1,000 c c per day

3 *To provide all essential foods in adequate amounts to cover the anabolic stage of post-operative convalescence* Such provision should begin around the third post-operative day, despite the fact that it may be wasteful for a time in subjects in a prolonged catabolic phase, since it will enable them to begin regaining their balance at the earliest possible moment

The administration of food at this stage should be a gradual process, so that by the end of the first post-operation week the patient should be in receipt of sufficient calories, nitrogen and potassium so as to be in good positive balance The exact amounts given will depend upon the presence or absence of any associated abnormal losses, so that amounts varying from 2,000 to 4,500 calories per day may be necessary The oral route is best but an adequate intake with suitable diets can be maintained via a gastrostomy or even a jejunostomy

4 *To watch for abnormal losses and to redress the imbalance on a quantitative basis* Attention to this problem begins during the operation with the immediate correction of whole blood losses Along with high intestinal obstruction and large surface area burns haemorrhage produces the most rapid form of dehydration In its severe acute form death quickly follows less severe losses at operation are carried as nutritional burdens which have to be supported in the post-operative phase Hypotension and tissue anoxic changes may be early features of this deficiency (see sections on cardiac arrhythmia and cardiac arrest) Since Wangensteen (1942) and Gross (1940) demonstrated the importance of the immediate and accurate replacement of blood lost during operations the problem has been overcome by the frequent weighing of soiled mops during the operation so that blood loss can be replenished by the intravenous blood drip pari passu with the losses The blood balance should be further checked after 48 hours by a routine haematocrit and Hb value examination

(a) *Serum and Near Serum losses* After severe burns the loss of whole serum calls for its replacement as plasma The chest surgeon sees occasionally an almost comparable near-serum loss into the pneumonectomy space when a large quantity of fluid electrolyte and protein often heavily blood-stained accumulates in a short time Although technically it does not disturb the balance yet it is lost to the circulation and may impose a nutritional burden, clinically seen as hypotension or as peripheral oedema usually in the form of a sacral pad or as a delayed recovery from the operation The possible association of such losses with post-operation atrial fibrillation has been noted

(b) *Water electrolyte losses* and *p*H changes are seen most commonly by the thoracic surgeon as the result of either vomiting upper alimentary tract fistulae or respiratory acidosis following operations on patients with emphysema this latter condition causing hypernoea with H_2O loss Frequently accompanying the dehydration there is a differential loss of base or acid ions for example vomiting and upper alimentary tract fistulae tend to alkalosis while diarrhoea lower alimentary tract fistulae and emphysema lead to acidosis

5 *To recognize Nutritional Deficiency Syndrome arising because of imbalance* (a) *Hypotension due to the low Na syndrome* The heart as a pump and the peripheral resistance play important roles in the maintenance of blood pressure after operation yet it is deficiencies affecting the circulatory blood volume and its constituents that are most likely to be responsible for a low blood pressure Apart from whole blood losses hypotension is largely a problem of Na balance After an operation in the absence of abnormal losses and in the presence of normal Na conservation by the kidneys a fall in serum Na level occurs presumably due to its migration into the cells This effect may be exaggerated by anoxia high K losses and excessively large Na infusions given too rapidly The low Na syndrome may be met following operations on patients with congestive heart failure particularly if they have been treated by dehydration therapy beforehand and if they are given large quantities of H_2O alone after operation

Treatment should be directed firstly towards the rehabilitation of the cells by the giving of calories protein and K in order to drive the intracellular Na back into the circulation The use of whole blood for this purpose is excellent Later Na should be given slowly in reasonable amounts up to 300 Meq/day unless in addition there are large external losses other than renal to be made up

(b) *Hypokalaemia* Potassium is lost steadily in the catabolic phase after operations due to cell disintegration it may be lost in excess of its Na equivalent where cell dehydration alone occurs Nevertheless, if a reasonable urine output is maintained then the serum K levels found are usually normal

If a sudden acute loss of K occurs, for example as a result of acute Cl loss with alkalosis from vomiting or upper alimentary fistulae, then hypokalaemia follows, clinically recognizable by profound muscular weakness, mental apathy and disorientation, anorexia and possibly with abdominal distension due to ileus and a cardiac arrhythmia seen with typical E C G changes Treatment is by the careful administration of KCl in order to correct both deficiencies, given preferably by mouth

(c) *Hypoproteinaemia* After operation this is most often due to an overloading of the circulation with salt and consequently with water, resulting in the expansion of the intravascular space and protein dilution Other causes are prolonged starvation from a failure to supply adequate calorie and N intake after the fifth post-operative day, liver damage, and excessive protein loss caused by sepsis, albuminuria or occasionally as seen into the pneumonectomy space

The results of persistent hypoproteinaemia may be seen as oedema, poor wound-healing or the persistence of a paralytic ileus

Treatment begins soon after operation by the strict control of fluid balance and later by the provision of an adequate calorie and N intake In an osmotic emergency the giving of intravenous plasma is recommended, intravenous and oral protein-hydrolysates are helpful if the former is given slowly, and always providing an adequate calorie intake is maintained at the same time

Diagnosis of the nutritional deficiencies

At present exact scientific methods of assessing nutritional deficiencies are inadequate The history and clinical condition of the patient are the best guides, combined with assessment of the fluid and electrolyte losses due to any acute disorder such as vomiting Where the patient has been under observation for some time, as in the post-operative period, fluid and electrolyte balance charts, where the measurement of both these factors in the fluid lost, e g vomit or the leakage from fistulae into the chest or from gastro-oesophageal anastomoses, will be made Add to these the insensible losses from the skin and lungs of approximately 1,000 c c per day and an excellent basis for restorative therapy exists Occasionally biochemical measurements are of great help

The serum sodium level is utilized by many as a guide in severe losses but it must be remembered in the less severe losses that good functioning kidneys will preserve osmotic pressure by excreting water and thus apparently normal values may be found Similarly serum potassium estimations are sometimes very helpful In both these cases the use of the flame photometer will provide a very easy and rapid answer

Plasma hydrogen ion concentrations and serum bicarbonate estimations are excellent where changes such as acidosis or alkalosis are suspected, particularly where a breakdown in respiratory (due to intracranial lesions, drugs, emphysema) or renal control occurs

Changes in body weight, if an efficient simple method were available, would be of great help in assessing losses of total body water

Measurements of urinary chloride or better still sodium output per day is still believed to be a very useful control test This, of course, always presupposes that a normal renal function and normal suprarenal and pituitary control are present and that there is no upset in plasma hydrogen ion concentration , facts which sometimes cannot be taken for granted.

Replacement therapy

In uncomplicated cases, as has already been stated, the body s only requirements are those of 1,000 c c of water a day to cover obligatory losses and the basal requirement of

between 1 300 and 1 500 calories per day which may be given for example as glucose 300 to 350 grammes In this way starvation with the resulting breakdown of proteins for energy purposes can be spared The route employed should be the mouth whenever possible but as so often happens this may be impossible making the taking of these basal requirements difficult Glucose solutions in greater concentration than 10 per cent thromboses veins and leakage takes place via the kidneys if the administration is too rapid 0 5 gramme per kilo of body weight per hour seems to be maximum The use of intravenous fat emulsions therefore has a place here when they become generally available

Electrolyte administration should only be sufficient to replace losses Normal saline has long been the routine electrolyte solution used but it must be remembered that it is isotonic only with the red blood cells and contains excessive amounts of the chloride ion which with a poor renal function is likely to upset hydrogen ion concentration values The use therefore of a true physiological saline is recommended this may be made up as follows 0 64 gramme NaCl 0 25 gramme $NaHCO_3$ 0 0018 gramme KCl The well known Hartmann s solution is equally good containing additional buffer in the form of lactate Both these solutions are isotonic with tissue fluid and contain all the essential bases including potassium to compensate for the continued inevitable renal losses of the base and to provide extra essential rebuilding materials for the cells Where renal damage is severe for example in anuria the provision of electrolytes and particularly potassium may be dangerous leading to cardiac arrest

Acute blood losses must always be made up by immediate equivalent transfusions Any delay enables plasma volume to be made up from the tissue spaces so that late trans fusions may increase the normal blood volume leading to embarrassment of a heart with a low reserve Thanks to the work of Wangensteen (1942) and Gross (1949) we now have a method of measuring blood losses during operation since it enables minimum losses to be known at any time thus enabling correct compensation to be made The only possible blood substitute on a more than temporary basis is dextran which has a particulate mass of roughly the same size as the red blood cell.

The infusion of plasma except in acute osmotic disturbances for example where local oedema occurs post-operatively has little to recommend it Intravenous protein is only slowly utilized by the tissues as an available source of nitrogen and in addition plasma always carries the risk of homologous serum jaundice Amino acids administered intravenously however have a place in the treatment of protein deficiencies their greatest disadvantage being that slow rates of infusion are necessary otherwise a gross spill-over into the urine occurs

The rate of intravenous administration It has been customary in surgery for many years to force fluids but more recently the dangers of this particularly where 0 9 per cent NaCl solutions are used, have been realized, and most surgeons would agree that a slight fluid deficit is better than any degree of excess However rapid intravenous administration may occasionally be justified for example as suggested by Marriott (1947) in acute circu latory failure due to salt or mixed water and salt deficiency The administration of 3 to 4 litres in the first 24 hours may be necessary under these circumstances Acute whole blood losses must be replaced equally rapidly

Dangers of over hydration The kidneys represent the most important safeguard for water and electrolyte therapy the statement that given water and salt the kidneys will excrete the excess differentially as required is so nearly true as to have become dangerous when we realize that patients can be and are killed by its use The reason for this is that the kidneys are often by no means normal and their ability to concentrate and excrete

chlorides is depressed In children, elderly patients and chronically debilitated patients this is usually the case

In addition to this an obligatory degree of salt retention occurs post-operatively, which is exaggerated by the administration of saline (Moore) and thus the kidneys are unable to excrete excess salt The normal salt intake varies from 5 to 10 grammes per day

A second important point is that water administered with salt in isotonic solution is tied and is not available for the replacement of fluid lost by evaporation or in the urine Therefore if the kidneys are to provide " free water " they have to excrete urine containing a higher concentration of saline than that administered, if they are unable to do this oliguria or even anuria may result

Oedema, particularly pulmonary oedema, is therefore the natural result of over-hydration and may produce a rapidly fatal issue, aggravated by the associated anoxic effect on the tissues and their capillary permeability. Lesser degrees of oedema such as those found around operation sites, anastomotic suture lines and wounds will delay healing and interfere with the physiological function of the parts

Lastly, the administration of isotonic saline solution will produce dilution of proteins and red cells in the serum

Summary

Electrolytes in excess of daily requirements should not be administered except to replace known or suspected clinical losses

" Free water " must always be provided to replace insensible losses and to cover renal function This should be given by mouth wherever possible but can be supplied intravenously as solutions of glucose

In cases of malnutrition in its widest sense, provision must be made for water, calories, nitrogen and electrolytes, the latter to include both essential bases, sodium and potassium

Vitamins

Vitamins are no longer reserved for the cure of certain rare diseases but are known to be essential for normal cell metabolic processes Sub-clinical deficiencies are common Their lack may be responsible for such conditions as delayed wound healing and poor resistance to infection In addition it is widely recognized that many surgical procedures in themselves may cause vitamin deficiency diseases, as in the instance of gastric resections precipitating a gross vitamin B complex deficiency

Vitamin A deficiency is uncommon in surgery but it is usual where there is evidence of general malnutrition to give vitamin A, as we know that it plays a definite part in resistance to infection

The vitamin B complex is of great importance because it is known to be essential for tissue respiration The principal deficiencies met with in surgery seem to be the fractions thiamine nicotinic acid and riboflavine, although whole B complex should always be administered These deficiencies appear to be particularly high following radical gastric resection as described by Brain and Stammers (1951), and as result of modern chemotherapy agents on occasions

Gross vitamin C deficiency in the adult population is now almost unknown, but the association of subclinical deficiency with poor wound healing and anaemia is common Vitamin C appears to be responsible for the maintenance and production of intercellular substances, for example collagen, bone matrix and the intercellular tissues of capillaries Poor wound healing due to vitamin C deficiency is recognized throughout surgery

Fat-soluble vitamin deficiencies in surgery are rare but special mention might be made of vitamin K deficiencies which are met with in jaundiced patients and in addition vitamin K may be used to correct the unduly low prothrombin states brought about by certain anti coagulant drugs such as Dicoumarol or Tromexan

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In cases of malnutrition in its widest sense, provision must be made for water, calories, nitrogen and electrolytes, the latter to include both essential bases, sodium and potassium

Vitamins

Vitamins are no longer reserved for the cure of certain rare diseases but are known to be essential for normal cell metabolic processes Sub-clinical deficiencies are common Their lack may be responsible for such conditions as delayed wound healing and poor resistance to infection In addition it is widely recognized that many surgical procedures in themselves may cause vitamin deficiency diseases, as in the instance of gastric resections precipitating a gross vitamin B complex deficiency

Vitamin A deficiency is uncommon in surgery but it is usual where there is evidence of general malnutrition to give vitamin A, as we know that it plays a definite part in resistance to infection

The vitamin B complex is of great importance because it is known to be essential for tissue respiration The principal deficiencies met with in surgery seem to be the fractions thiamine, nicotinic acid and riboflavine, although whole B complex should always be administered These deficiencies appear to be particularly high following radical gastric resection as described by Brain and Stammers (1951), and as result of modern chemotherapy agents on occasions

Gross vitamin C deficiency in the adult population is now almost unknown, but the association of subclinical deficiency with poor wound healing and anaemia is common Vitamin C appears to be responsible for the maintenance and production of intercellular substances for example collagen, bone matrix and the intercellular tissues of capillaries Poor wound healing due to vitamin C deficiency is recognized throughout surgery

Fat-soluble vitamin deficiencies in surgery are rare but special mention might be made of vitamin K deficiencies which are met with in jaundiced patients and in addition vitamin K may be used to correct the unduly low prothrombin states brought about by certain anti coagulant drugs such as Dicoumarol or Tromexan

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PART II

THE SURGERY OF PYOGENIC INFECTION

CHAPTER 6

EMPYEMA

Though defined simply as a pleural effusion that is frankly turbid purulent and with a high cellular and protein content characteristic of an exudate, empyema is represented by many different grades of severity and extent dependent on the state of the underlying lung pathology and the nature of the organism A turbid effusion developing early during the course of a pneumonia treated adequately by sulphonamides and antibiotic therapy is often cured by aspiration and the use of drugs and suitable antibiotics but once pus with fibrinous deposits has formed surgical treatment is usually advisable to prevent chronicity continued sepsis and crippling of the lung and chest wall function. Treatment by aspiration chemotherapy and surgery are along the same lines whether the empyema belongs to the syn pneumonic type, usually streptococcal or the meta pneumonic (pneumo coccal) empyema

Treatment by antibiotics and sulphonamides has so altered the whole natural history of pneumonia and its sequelae that the previous differentiation of empyema into those that develop early in the pneumonia and those that follow the start of the lysis is of less significance now playing little part in diagnosis or treatment

It will be most unfortunate if aspiration combined with antibiotic therapy (local and general) is regarded as an alternative treatment to surgery In early pleural infection after gun-shot wounds it was clear that penicillin could sterilize many empyemata (d Abreu Litchfield and Thomson 1944) but did not always enable the products of infection to be totally removed when this happened lung and chest wall function could become per manently crippled Surgical and antibiotic therapy must be employed coincidentally in many patients with pleural infection.

The newer conceptions of treatment

The modern treatment of pleural empyema is designed to abolish infection produce full lung re-expansion and to avoid a rigid chest wall or an empyema scoliosis of the spine Those aims are easy to achieve if the diagnosis is made and the operative measures accurately timed The surgical treatment of an empyema is never an acute emergency but is based on deliberate planning after a full clinical bacteriological and radiological assessment

Since the time of Hippocrates when empyema was treated by drainage many wars have aroused the interest of surgeons in pleural infections and the apparent conflict between the need for opening the chest to evacuate the pus and the dangers of open pneumothorax have only been banished by the events of the last war Chemotherapy physiologically sound anaesthesia and adequate surgical technique have abolished the fears of producing an open pneumothorax in an infected pleural cavity The insistence by Evarts Graham (1918) that open pneumothorax should be avoided in patients with thin streptococcal

effusions was based at that time on sound physiological and pathological principles; moreover, the clinical test of ignoring his advice was reflected in a mortality rate of 80 per cent when open drainage was performed in early streptococcal empyema accompanying a pneumonia. Today, the dangers to which he drew attention can be overcome by scientific management of the empyema. Graham and Bell showed that open drainage performed before encapsulating adhesions and a stiffening of the mediastinum had developed, seriously upset the sound lung because of the transmission of a positive atmospheric pressure through a mobile mediastinum, and the onset of paradoxical breathing in a patient with a low vital capacity and open pneumothorax was fatal. If the pleural cavity is to be opened safely we now know that the mediastinum can be steadied, as was done many hundreds of times during the last war for the treatment of early infection of a haemothorax, by the anaesthetist controlling respiration so that active mediastinal movements do not follow.

The chemotherapeutic control of toxicity in streptococcal empyema has greatly decreased the illness of these patients and helped to maintain a reasonable vital capacity. At the same time the intrapleural injection of drugs has allowed the inflammatory process to proceed along lines far more akin to the fibrin-producing effects of pneumococcal infections and decreased the delay before operative drainage or decortication can be done.

Etiology and pathology

Inflammation of the pleura is always secondary, the infective process spreading to it, from the lung in most instances but occasionally from injury, from sub-diaphragmatic abscess, from osteomyelitis of the spine or ribs or as part of a septicaemia. The same pathways of infection are seen in tuberculous disease. By far the commonest type of pleural infection in civil life accompanies or follows pneumonia (syn-pneumonic or meta-pneumonic empyema), possibly the result of the rupture of a small sub-pleural abscess. Pleural infection, however produced, arouses the usual response of acute inflammation and the process may resolve completely or by repair fibrosis (commonly causing pleural adhesions), or may proceed to suppuration. A fibrous or dry pleurisy is the commonest manifestation but a sero-fibrinous or "wet" pleurisy is frequently met with in practice. Such effusions are usually straw-coloured exudates with or without a high leucocyte content and depending entirely on the defensive powers of the body, natural or bolstered up by chemotherapy, organisms may be present or absent.

With the increased survival rate of patients with acute pneumonia due to antibiotics and chemotherapy the number of serous effusions has increased. If the infecting organisms die the effusion will resolve and this is common, but it is important to remember that an effusion proved to be sterile at the first aspiration may subsequently become infected and sufficiently slowly to be overlooked in the absence of obvious pyrexia. Clinically this may be emphasized by realizing the numbers of patients who are now diagnosed as having pleural empyema when attending out-patient departments as ambulant apyrexial convalescents. The intensive chemotherapy practised in the acute stages of the pneumonia may have exerted a bacterio-static rather than a bactericidal action, followed by a slow, undramatic recrudescence.

When the pleural exudate is grossly turbid and purulent an empyema exists. The fluid is more viscous, has a higher specific gravity with an obvious increase in protein, cells and frequently organisms; even at this stage natural resolution, aided by complete aspiration and chemotherapy, especially if employed intrapleurally and parenterally, is possible but the complacent assumption that this will follow is most unwise. Unless the infection is eliminated completely and the lung re-expands fully a fibrino-thorax may develop, which

f not diagnosed and treated may produce constriction of the lung and loss of chest wall novement with permanent damage to respiratory function

The effects of inflammatory pleurisy

Resolution may be so complete in all types of pleurisy that loss of the potential pleural space may not follow though this does occur in most instances in varying degrees Even after a pleural empyema has been drained surgically the major part of the pleural cavity may remain free and I have seen an artificial pneumothorax produced for the treatment of a tuberculous process that developed in a patient who years previously had been successfully treated by surgical drainage for a pyogenic pleural empyema

More usually obliteration of wide areas of the pleural space follows the organization of the fibrin deposited on both the visceral and parietal pleurae This pleurodesis may diminish the lung function on that side and a complete fusion of the parietal and visceral pleura interferes considerably with respiratory function If these surfaces are kept apart by pleural fluid as in the type of quiet empyema that may follow inadequate penicillin therapy the fibrinous deposit may be gross both on the chest wall and visceral pleura In the absence of absorption with lung re-expansion or of surgical treatment it becomes rapidly organized on both surfaces in from two to six weeks after the start of the infection The invasion of the fibrinous deposit by small capillaries and their associated fibroblasts paves the way to true fibrous tissue the contraction of this tissue constricts the lung and cripples diaphragmatic and chest wall function by preventing the usual respiratory excursion The prophylaxis of the pathological process is by the operation of early empyema drainage and pleural toilet sometimes combined with lung decortication which will be discussed later Even after many months or years of this process the fibrous envelope on the lung and parietal pleura can be removed surgically through a plane of cleavage that can be developed between the new false membrane and the true pleura Although histological examination of this constricting layer shows that fibrous bands do spread deeply into the true layers of the pleura the membrane has a capacity for resisting the complete cirrhotic invasion of its shiny serous surface and this can be demonstrated easily during the operation of decortication

The shape and location of pleural effusions

In large effusions the empyema may be total filling a large part of the hemithorax compressing the lung and displacing the mediastinum to the opposite side even large empyemata may however produce no such displacement (see Fig 6 7) More usually the empyema is basal the fluid collecting in the costal sinus and spreading upwards and outwards towards the axilla (Fig 6 1)

Encapsulated empyema may provide apical interlobar or parietal collections of pus (see Figs 6 2 and 6 5) Since a lung released from compression either as the result of aspiration or drainage may expand unevenly in the early stages bizarre shaped *empyemata* of complicated shape may be seen If the base of the lung expands before the apex an hour-glass shape may result and this may provide difficulty in the post-operative manage *ment of a drainage* tube which may have to be inserted higher and higher into the apical pocket Before decortication was used in the infected haemothorax of warfare *these multi locular* cavities were common On other occasions the empyema may have anterior and posterior compartments calling for drainage of each separately The shape and character of the empyema may be altered by the *development* of a broncho pleural fistula which

produces a fluid level on the radiograph (see Fig 6 4), a faulty diagnosis of lung abscess may result



Fig 6 1—Left basal empyema (pneumococcal)
There is still consolidation of the lower lobe

Complications of an undrained persistent empyema

The clinical features of " chronic " empyema are reflections of the pathological process if not drained the empyema may rupture into the lung (broncho-pleural fistula) or on to the parietes (empyema necessitans) The diaphragm, the pericardium and the oesophagus have a strong resistance to the spread of inflammation beyond their membranes, though such a process is a rare cause of pleuro-oesophageal fistula When an empyema necessitans develops its external site is not always over the area of the maximum content of the pleural empyema and the pus may track along the plane of intercostal vessels to find egress from the pleural abscess commonly the site is placed anteriorly on the chest or anterior abdominal wall

The development of a broncho-pleural fistula is undesirable for through it re-infection of the empyema space frequently recurs and is a cause of chronic empyema, the spread of pus through the fistula may set up lesions in the same or opposite lung General toxaemia with severe secondary anaemia and the visceral changes associated with chronic sepsis develops and cerebral abscess may become a complication In amyloid disease associated with pleural sepsis there is usually an associated tuberculous process

Bacteriology of acute empyema

The achievement of chemotherapy has largely obliterated the clinical differences that used to be a pronounced feature of empyema due to differing organisms in previous days a streptococcal infection frequently produced a thin sero-purulent effusion with greater toxicity than that following a pneumococcal one with its thicker, fibrinous pus It is common now to find large quantities of fibrin in a streptococcal empyema that has been treated by chemotherapy and the response of streptococcal infection to these agents is so rapid that gross toxaemia is rare

Staphylococcal empyema, once so serious in the absence of an efficient chemotherapeutic

substance is usually a sequel of septicaemia and the co-existence of multiple lung abscesses especially in infants and children is notable Their response to penicillin and the other antibiotics is usually good and after the initial stages the course of an empyema in these patients may not differ from other pyogenic pleural infection though drainage is usually avoidable when they complicate staphylococcal pneumonia (see p *132*) * Serious problems however develop if the staphylococcus is resistant to antibiotics

The putrid empyema

This the most serious of all pleural infections is caused by a multiplicity of organisms many of which are symbiotic such as the Vincents organism pyogenic organisms are usually present and the *B coli* may be recovered. The pus has a foul odour and is usually brown or greyish in colour Quite the commonest focus is from a rupture *of a lesion in the* lung parenchyma such as abscess suppurative pneumonitis or bronchiectasis The condition is seen as a terminal event in carcinoma of the lung when abscess or lung gangrene has developed distal to a blocked bronchus Putrid empyema responds poorly to chemotherapy alone and is the one empyema that calls for early urgent surgical treatment The under lying pathological processes such as bronchial carcinoma or lung abscess make the use of bronchoscopy an important preliminary examination in patients of carcinoma age urgent pleural drainage *is indicated and in patients with spreading suppurative pneumonitis* pleuro-pneumonectomy may be indicated This type of empyema has become rare

The effect of chemotherapeutic and antibiotic substances on the natural history and bacteriology

Although most of the patients with empyema who reach a surgical ward have been receiving chemotherapy this is not invariable and effusions typical of the causative organism may be present The severe toxaemia that accompanies a streptococcal empyema is associated with a thin purulent effusion free from fibrin and therefore unlikely to have fixed the lung to surrounding areas open drainage of such thin pus will be dangerous because of the movements of the mediastinum during and after the operation and it was this factor that led Evarts Graham to condemn early operation the principle then enunciated still holds good in this type of patient but must not be extended to cover the group of patients who have been treated by penicillin and who in addition to an absence of toxaemia and low vital capacity have thick pus in their pleural cavities The war time results after wide thoracotomy for clotted infected haemothorax empyemata have dispelled the idea that such major operations are dangerous in the presence of pleural infection (Churchill, 1945) The modern management of streptococcal empyema which usually accompanies the pneumonic process *is to sterilize if possible the lung the blood stream* and the pleural cavity before recourse is made to operation the chief aim of which will be to remove the products of the now benign empyema and to restore full lung re-expansion

Diagnosis of empyema

Apart from infection after trauma or major intrathoracic operations the diagnosis is based chiefly on the knowledge that the patient has been or is suffering from a lung infection and on physical and radiological examinations the accuracy of which is confirmed by a thoracic paracentesis Reliance cannot be placed upon the classical features of syn pneumonic or post pneumonic effusions because drug and antibiotic therapy of serious or

* Staphylococcal empyema in infants is usually preceded by a spontaneous pneumothorax, com plicating a staphylococcal pneumonia (see *Fig 7 5*)

potentially dangerous respiratory infection suppresses or alters many of the signs and symptoms. Rare indeed is the temperature chart which shows recrudescent pyrexia following the abrupt fall in temperature after a dramatic crisis or lysis, because the chemotherapeutically treated lobar pneumonia seldom shows much pyrexia after 48 hours. Nor is the malaise that used to accompany the raised temperature so distinctive and the patient may well be progressing to a hastened convalescence before the chest is noted to be moving badly and before dullness to percussion over an insidiously developed effusion is detected. A more usual clinical picture is that convalescence is slower than hoped for and is marked by symptoms such as lassitude, cough and slight pyrexia. The deceptively slow course of the disease favours the opinion that a chest radiograph should be taken before the patient is allowed to resume normal duties after a pneumonia.

Frequently there is no shift of the mediastinum to the healthy side, for large effusions can collect without displacing either the trachea or the apex beat; dullness to percussion and the absence of vocal and tactile fremitus are more reliable physical signs. Poor movements and retraction of the ribs over the involved area are common. Breath sounds may be heard through purulent effusions, especially in infants and children. If any doubt exists as to the diagnosis radiographs in the postero-anterior and lateral position must be taken, but this step should be substituted by an exploratory aspiration under local anaesthesia if X-rays are not available. In hospital practice it is inexcusable to forego radiographic examination, for not only does it confirm the extent of the effusion but may disclose a hitherto unsuspected but causative disease in the thorax.

The *technique of aspiration* is too well known to call for description, but fluid is often withdrawn after previous failures by observing a few simple rules, the chief of which are the avoidance of too low a site for aspiration in the usual posteriorly placed effusion, the necessity for an accurate counting of the ribs when the fluid is in the more unusual sites such as interlobar, anterior or apical collections and the use of a really wide-bore long needle. At each diagnostic and therapeutic aspiration care is exercised to prevent the entry of air into the empyema cavity, for its addition increases the rate of absorption of pleural fluids which may be serious in early infected toxic purulent effusions. The entry of large quantities of air will lead to the further collapse of the lung and so defeat one of the chief aims of treatment, lung re-expansion. The accident of air entry can be prevented by the use of a two-way tap on the syringe or of Potain's apparatus.

Radiological appearances of empyema

Typical basal empyema. The basal opacity in the usual uncomplicated empyema has a margin that slopes up to the axilla with medial compression of the lung (Fig. 6.1); the lowest part of the effusion on the right side cannot be seen, usually because it fades off into the diaphragmatic surface of the liver shadow, but on the left side the stomach gas bubble usually enables an estimate of it to be made. The same radiological appearances will naturally accompany a tuberculous or simple effusion and the differentiation can only be established on the history and the examination of a withdrawn sample of fluid.

Encapsulated empyema. Many patients with this condition may be ambulant for several weeks before progressive disease makes them seek medical advice. The radiograph shown in Fig. 6.2 was taken of a woman of 45 who had been treated five weeks previously for pneumonia at home and attended the out-patient clinic because of "anaemia". This fact and the radiological appearances may give rise to confusion with other space-occupying lesions and suggest diagnoses such as tumour, abscess or consolidation of lung parenchyma, and lung cysts occupied by fluid. In the last condition secondary infection may so compli-

ate the picture that surgical drainage of a cyst may be carried out under the belief that an empyema is being drained Such an error may lead to a continual chest wall fistula but I know of two occasions on which drainage has been followed by alarming haemorrhage from incision of the large abnormal vessels that may supply such cysts

In the surgical management of encapsulated empyema the wall of the cavity must be inspected with great care a biopsy being taken to make sure that ciliated columnar epithelium is not present Error in diagnosis is possible when the cyst has an open bronchial connection the operator thinking he is dealing with an empyema complicated by broncho pleural fistula

The oval encapsulated empyema may simulate the appearance of thoracic neurofibroma or even of hydatid cyst



FIG 6-2 —Large encapsulated empyema (pneumococcal)

Interlobar empyema may be confused especially with a collapsed right middle lobe the usual error being to regard the atelectatic segments as an interlobar effusion Clinical confusions over the recognition of interlobar effusions are accentuated by the commonly accepted assumption that most of these encapsulated empyemata have their origin in a ruptured lung abscess that has secondarily involved the space affected (Neuhof and Copleman 1941)

The natural history of encapsulated empyema is that many follow the rupture of a local lung abscess into the pleura after limiting adhesions have developed to prevent a spread of the inflammatory process If the adhesion formation is incomplete a bilocular or multi locular abscess cavity may develop the spaces often separated by a considerable distance

Associated with encapsulated empyema may be a co-existent serous effusion para centesis of the clear effusion may confuse the diagnostic picture the circular or ovoid empyema being regarded as a neoplasm or other intrapulmonary lesion which has caused a pleural effusion

The characteristic radiological appearances of these enclosed empyemata include an oval outline, the base of which is adjacent to the chest wall, or diaphragm (see Fig 6 2) If there is a broncho-pleural fistula or air has been introduced at paracentesis a fluid level will be present Such an appearance may lead to a faulty diagnosis of lung abscess Perhaps the most important radiological feature of encapsulated empyema is the sharpness of the margins seen, and the same applies to parietal empyema

Although the localized empyema is usually sited laterally or in the main fissure or against the chest wall (parietal empyema) it may be detected radiologically at the apex of the pleura, or at its mediastinal surface or between the base of the lung and the diaphragm In the rare para-cardiac type confusion may result in a diagnosis of enlargement of the heart or of pericardial effusion



Fig 6 3 —Complicated empyema

Note basal empyema and fluid level below left clavicle In the lateral radiograph this lay anteriorly Both empyemata were drained separately

Empyema with broncho-pleural fistula Bronchial connections with an empyema produce a fluid level in most instances, the condition may be confused with that of lung abscess (Fig 6 4) The differentiation can be made by a careful study of the segmental distribution of the lung, lung abscess rarely traverses the boundaries of its own segment and on the lateral radiograph its fluid level does not reach across the whole pleural cavity which is often the case with an empyema

Unusual but important causes of empyema Each year a few patients are seen with pus in the pleural cavity that has its origin in actinomycotic lesions of the lung or as the result of serious lung disease, the most common examples of which are carcinoma or other obstructions of the bronchus, lung abscess, bronchiectasis or tuberculosis (Fig 6 5)

The management of acute empyema

The evacuation of the empyema, the re-expansion of the compressed lung to obliterate the empyema space, the restoration of lung and chest wall function and the destruction or



(a)



(b)

Fig 6·4 (a) and (b)

(a) Pyo-pneumothorax with broncho-pleural fistula.
(b) The lateral radiograph.



Fig 6·4 (c)



Fig 6·5

Fig 6·4 (c).—A week later than X rays shown in Fig 6·4 (a) after simple drainage (closed)
The tube is still i position.

Fig 6·5 —Parietal empyema
The right lower lobe is collapsed a a result of bronchial adenoma (Dr Brian T ylor s patient.)

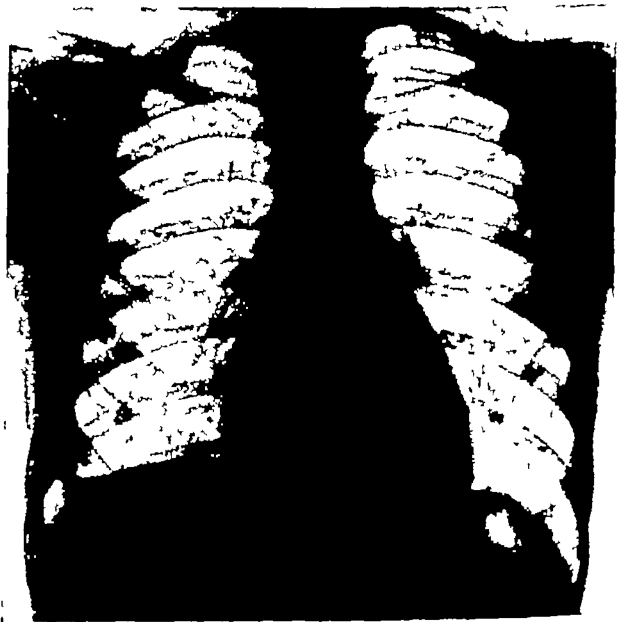
over the visceral and parietal pleura is softer and peels readily In the post-operative treatment two catheters, one apical and one basal, as first advocated by Price Thomas and



(a)



(b)



(c)

FIG 6 7

(a) Right total empyema (pneumococcal) treated by pulmonary decortication
Pre operative radiograph

(b) The day after decortication
Portable radiograph showing the apical and basal intercostal catheters in position

(c) Full lung re-expansion
Radiograph taken two months after that of Fig 6 7 (b)

Cleland (1945), in the treatment of clotted haemothorax, are used and connected to a small motor that provides continuous suction, as the aim is to produce full and rapid lung re-expansion

-operative management

The chief aims are the maintenance of free continuous drainage and the rapid rehabili n of lung and chest wall function by physiotherapy In a closed system of drainage ;ant attention must ensure that the system is efficient and that the column of fluid e tube that leads beneath the water in the bottle moves up and down with each inspira and expiration

The extent of lung re-expansion can be measured by radiological examinations but the erature chart the rapid recovery of a sense of well being by the patient and the return iest wall movements are all useful indications of satisfactory progress The tube site

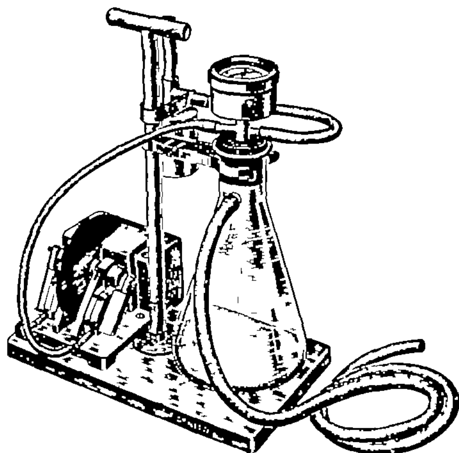


FIG 6·7 (*d*)—Roberts motor for providing continuous suction pressure (G U Mfg Co)

djusted according to the radiological appearances the empyema space may evolve into irre shapes because lung expansion is irregular In a large empyema the basal section he lung often expands more rapidly than the areas forming the anterior and upper ndaries of the cavity and the tube must then be pushed up to a higher level to avoid upper compartment becoming blocked off from the drainage opening

The empyema cavity may become hour-glass-shaped or bilocular with one pocket behind one in front of the lung Such states may indicate the need for placing another tube e anteriorly or at a higher site after further rib resection The need for this can often prevented by deciding at the time of the first operation to employ decortication instead imple drainage Especially so is this when the pre-operative radiograph indicates the lihood of *post-operative difficulties from uneven lung re-expansion* because of loculations to pleural adhesions

When to discard the tube Injudicious removal of the drainage tube is the single commonest cause of "the chronic empyema" The tube should only be discarded when there is undoubted proof that the empyema cavity has been obliterated because the parietal and visceral pleura are in contact in all areas except along the line of the tube track This is detected most readily by studying pleurograms or sinograms obtained radiologically after the instillation of lipiodol into the "sinus" If both the lateral and postero-anterior views demonstrate that only a tube track is visible, the drainage tube is finally removed after gradual shortening



FIG 6 8—A sinogram

A large empyema has been drained the basal portions of the lung re expanded rapidly and the tube had to be inserted further in to provide drainage for the upper part of the empyema space The lipiodol-filled cavity is an indication for retaining the tube

The closed system can be dispensed with long before pleural symphysis has occurred and the patient is allowed out of bed at an early date

The wearisome repetition of this old story about the time for tube discarding is a duty that has its apology in the fact that most of the chronic empyemata referred to a Thoracic Surgical Centre recurrently indicate that the lesson has not yet been learnt universally

CHRONIC EMPYEMA

A definition of chronicity based on a time interval of a certain number of weeks is hardly related to etiology or to the therapeutic measures already tried, but perhaps an arbitrary rule to grade all empyemata of over six weeks' duration as "chronic" may be of value A persistent collection of purulent or fibropurulent material in the pleural cavity may follow late diagnosis, inadequate drainage or a lesion of the lung parenchyma such as fistula, bronchiectasis, lung abscess or new growth and these possibilities must be borne in mind when a chronic empyema is presented for treatment By far the most frequent cause of the condition is inadequate drainage of a post- or syn-pneumonic empyema and the blame may be attributed to delay in surgical evacuation and to the premature removal of the drainage tube before the parietal and visceral pleural layers have become adherent after full lung re-expansion

This being so the cure of the condition is usually by simple re-drainage at the correct site and the energetic pursuance of physiotherapeutic measures Sometimes these aims can be achieved more rapidly by the operation of decortication when the empyema is re-explored and this measure is in increasing use today

The object is to encourage lung expansion after or co-existent with the removal of the empyema contents, and a mutilating thoracoplasty should be avoided as long as possible and indeed is rarely employed in a thoracic department for chronic empyema, except after total pneumonectomy for cancer or tuberculosis when infection has followed

Pathology of chronic empyema

Whether drained or undrained the walls of an empyema steadily absorb fluid so that the cavity contents become thicker and thicker with a continuous deposition of fibrin on the parietal and visceral pleura and its infiltration by fibrous tissue which imprisons the lung and progressively diminishes the movements of the chest wall and the diaphragm Massive adhesions may turn the cavity into a multiloculated mesh in the pockets so formed entrapped pus cannot reach the drainage tube or be removed by an aspirating needle This process not only leads to the deposition of thick masses but by preventing lung and chest wall function defies the natural tendency for cavity obliteration The cavity may be repeatedly re-infected by organisms reaching it from an associated broncho-pleural fistula Persistent undrained infection leads to chronic ill health, often without pyrexia and accompanied by a failure of bone marrow formation so that leucopenia may be present instead of the expected leucocytosis Amyloid disease rarely develops unless there is an associated tuberculous infection Metastatic brain abscess may supervene and a spread of infection through a broncho pleural fistula may cause a bronchopneumonic process in the contra lateral lung

The chest wall becomes progressively shrunken and immobile and the ribs approximate or overlap each other (tiling of the ribs)

The underlying lung though constricted may retain its normal appearance for many years but progressive loss of respiratory function is evident from studies performed after lung decortication in which little evidence of gaseous exchange can be obtained by the usual physiological tests even in the presence of a radiograph showing full re-expansion The lesion causing this may either be a fibrous replacement of the lung alveoli or an obstruction of the capillaries adjacent to the alveolar wall

Other causes of chronicity Tuberculous disease actinomycosis and underlying lung diseases such as persistent collapse of a lobe bronchiectasis lung abscess suppurative pneumonitis and carcinoma are causes of chronicity and their existence may not be established until weeks or months after an empyema has been drained. Naturally a higher proportion find their way to special chest units than to general surgical wards they are diagnosed by suspicion in a patient with an unusual clinical history and by careful examination of the radiographs supplemented by other examinations such as bronchoscopy bronchography and bacteriology Foreign bodies such as portions of drainage tubes or gauze are rarely seen and osteomyelitis of a rib in my experience has never been the cause of a persistent sinus but is the result of a persistent inadequately drained empyema

These unusual causes of chronic empyema must not allow us to forget that the cause in 80 per cent of the patients is delayed or inadequate drainage

The investigation of chronic empyema

The patient may present with evidence of an inadequately drained empyema usually with a sinus present through which pus ineffectively discharges from time to time or the chest wall may be intact as in examples of missed empyema these latter are by no means rare in these days of widespread chemotherapy which may have been given parenterally or intrapleurally or together The chief presenting symptom may be the expectoration of large quantities of purulent sputum and the patient may be regarded as suffering from lung abscess or bronchiectasis

The value of a careful history cannot be overestimated and from this a clue to the etiology is often obtained The story may disclose a long history of cough with sudden

development of serious illness, such is seen especially in patients with bronchiectasis or chronic lung abscess In the older age group a history of cough, possibly with haemoptysis which preceded a "pneumonia" followed by an empyema, detected by radiology or thoracentesis, should at once arouse suspicions of a possible underlying bronchial carcinoma

A high proportion of the patients give a history of repeated breakdown of a sinus that heals and discharges intermittently and to which multiple local remedies have been applied Such a sequel of a drained empyema inevitably indicates an underlying inadequately drained empyema

A complete clinical examination is followed by radiological examination, a study of the bacteriology of the sputum and of any discharge from a chest wall sinus The radiological appearances are variable depending on the state of the empyema cavity at the time of the examination If no fluid level is present the condition may be erroneously diagnosed as thickened pleura The condition of "thickened pleura" should always be questioned when the patient under consideration is in poor general health or when attacks of "recurrent pneumonia" and pleurisy have been diagnosed, thus distracting attention from empyema. This error is especially liable to be made when low-grade infection has involved a haemothorax, the sequel of a major intrathoracic operation or of trauma

The walls of a chronic empyema cavity may calcify Curiously this only appears to involve patients with a tuberculous infection or in those with a persistent low-grade infection in a haemothorax, the result of a gun-shot wound of the chest (Fig 6 9) Frequently a fluid level is seen, the air having gained access from a chest wall sinus, a broncho-pleural fistula or as the results of an aspiration

The state of the underlying lung is of prime importance In extensive, undrained empyema no details of the lung will be apparent If such an empyema is associated with total lung or lobar atelectasis, as in the case of a bronchus blocked by neoplasm, the trachea and mediastinum may be over to the side of the empyema instead of being displaced away from it Such an appearance indicates the need for bronchoscopy before treatment is directed towards the empyema

The radiological examination will disclose the extent of pleural thickening over the lung or chest wall and the degree of this may well decide whether simple drainage or lung decortication is to be practised, but such pleural thickening may rapidly absorb after adequate drainage and physiotherapeutic exercises

The bacteriological examination is essential though the basic infecting organism may not be detected at the first or subsequent examination especially so is this when the underlying process is tuberculous or actinomycotic and these two diseases should be in mind when a chronic empyema is being investigated, their possible presence is an important reason for performing a pleural biopsy at the time of the operation on the cavity

The extent of the cavity Sinograms taken after the instillation of iodized oil are helpful In addition to outlining the cavity which is usually larger on the lateral view than expected from the plain radiograph an unsuspected broncho-pleural fistula may be visualized Since iodized oil is not entirely non-irritant it should be sucked out of the cavity after the radiographs have been taken The presence or absence of underlying disease of the lung may often be investigated usefully by means of bronchography and this examination is necessary if the history suggests a possible bronchiectasis Although iodized oil introduced into the pleural cavity often delineates a broncho-pleural fistula the reverse is not true and oil introduced deliberately into the bronchial tree rarely finds its way into an empyema cavity

Treatment of chronic empyema

Surgical measures The many operations designed for the cure of chronic empyema might obscure the essentials of treatment which are adequate drainage or total evacuation of the empyema together with decortication of the thickened supra pleural organized exudate and vigorous physiotherapy The use of thoracoplastic operations often combined with Roberts flap operation or the complete saucerization of the cavity are largely obsolete so too are the operations designed for the surgical closure of a broncho pleural fistula following its isolation after dissection suture and an on laid muscle graft useful though this is in the occasional patient Most broncho pleural fistulae will heal when the object of obtaining pleural symphysis has been achieved for the essential mechanism that maintains patency of such a fistula is the persistence of the empyema pocket





Fig 6-9 Fig 6-10

Fig 6-9 —A chronic empyema with calcified walls, the result of gun-shot wound in the 1914–18 war Patient seen in 1950 when this radiograph was taken.

Fig 6-10 —A chronic empyema with obvious thickening of the visceral pleura preventing lung re-expansion an indication for lung decortication The empyema has been drained and the tube is still in place

The choice of operation The chief decision required is whether to employ adequate simple drainage or a wide thoracotomy incision through which pleural toilet and decortication can be effected Simple drainage has proved to be highly effective but it may have to be prolonged many months and is difficult to execute when the empyema cavity is loculated although drainage at more than one site may be effective in bilocular empyemata when there is an anterior and posterior collection of pus In very ill patients simple drainage will be selected as the operation can be performed under local anaesthesia with little or no disturbance

Local thoracoplastic operations are effective for moderate sized cavities if the un-roofing or " guttering " (Sellors and Cruickshank, 1951) is thorough The cavity in suitable patients may be packed daily until healing has followed from within outwards, or obliterated by the method of J E H Roberts in which a large flap consisting of the thickened parietal pleura and the intercostal bundles is fashioned by incisions above, below and anteriorly, leaving the hinge posteriorly This flap is then placed in apposition with the visceral pleura and maintained there by packing between it and the skin

Total thoracoplasty is rarely indicated except as already mentioned for empyema that has followed a pneumonectomy if the underlying lung is sound the operation of decortication is indicated in the type of empyema illustrated in Fig 6 10 where evidence that a healthy underlying lung exists if the lung is so diseased as to be valueless the operation of pleuro-pneumonectomy followed later by a limited thoracoplasty is likely to provide a better and quicker result than a total thoracoplasty executed in stages These extensive mutilating operations are so rarely necessary today that their description here is mainly of historical interest

The decline in the incidence and virulence of empyema continues Between 1948 and 1952, only 38 patients with pyogenic empyema due to or following pneumonia were under my personal care , one of these, an infant, died two hours after admission Thirty were over the age of one and of these 13 were treated by rib resection and drainage and 17 by decortication The average time spent in hospital after the operation was seven weeks for those treated by rib resection and three weeks for those in the decortication group The 7 infants under the age of one who survived all had staphylococcal empyema and all were treated conservatively by parenteral antibiotics, aspiration and the occasional use of continuous needle underwater drainage for tension pneumothorax

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CHAPTER 7

LUNG ABSCESS

Changes in the natural history and treatment of lung abscess

Clinical experience and the records of the literature indicate changes in the natural history of this disease in the last decade Almost a disappearing disease it lacks its previous malignity its more favourable course being influenced by the modern availability of effective chemicotherapeutic and antibiotic agents Together with a decline in severity a great fall of incidence has been noted the commonest lung abscess seen today is due to bronchial carcinoma

For a long time surgeons criticized the prolonged delay before open drainage was considered. Such delay was justified by physicians on the grounds that the mortality rate in patients treated surgically admittedly often in the late stages of exhaustion and toxaemia was as high as those treated expectantly (Maxwell 1934) Because of the brilliant results obtained by Neuhof and Touroff in 1942 by early surgery for putrid lung abscess the pendulum swung in favour of surgical treatment the delay being numbered in days rather than weeks before conservative treatment was abandoned By common experience a conservatively treated lung abscess that progressed well did so rapidly usually after the sudden expectoration of much pus after several days of high pyrexia and gross constitutional disturbance whereas the long-drawn-out illness of a less fortunate patient left him ill fitted for surgical drainage at the oddly arbitrary period of six to eight weeks when the abscess was frequently complicated by surrounding septic pneumonitis and bronchiectasis The surgical cure of such a patient often called for lobectomy rather than drainage because of the irreversible damage to the surrounding lung parenchyma and bronchi

When the case for early drainage had been accepted conservative measures were abandoned after ten to twenty days if the abscess had not decreased in size in a patient *clearly deteriorating the mortality rate fell dramatically as surgeons were presented* with patients before the last stages of a fatal illness The fact that Neuhof and Touroff (1942) had only 4 deaths in 122 early operations for lung abscess established at that date the superiority of external drainage over hesitant expectancy aided by a mass of drugs of doubtful value Admittedly their figures were not approached by other groups of surgeons but even the more normal mortality rate of 15–25 per cent was a great advance over the previous one of 50–60 per cent *

In Britain opposition to over persistence in conservative treatment came chiefly and lucidly from Brock (1947) who not only criticized the high mortality rate of medical treatment but stressed the permanent pulmonary suppuration that often remained after a so called cure had been achieved The main surgical interest in lung abscess and pneumonitis today is the exclusion of bronchial carcinoma as the cause In the cancer age group constant suspicion must be aroused when a diagnosis of lung abscess pneumonitis or

* Touroff Nabatoff and Neuhof (1950) have published a valuable follow up study of 165 patients who were treated by early one-stage drainage of whom 154 were operated upon in the pre-penicillin era 115 patients were followed up for over five years of these 100 were completely cured with no symptoms and a normal chest radiograph or bronchogram 15 patients only were regarded as unsatisfactory because of doubtful lung radiographs, or recurrent haemoptyses which occurred in 6 patients

"unresolved" pneumonia has been made Bronchoscopy and examination of the sputum for malignant cells will help to minimize diagnostic errors

During the last few years the introduction of antibiotic therapy has changed the method of treatment Excellent results are now being achieved by large doses of antibiotics given parenterally and combined with postural drainage The surgical drainage of acute lung abscess has almost disappeared from the lists of surgical operations

When surgical treatment is used it consists largely of excision of segments, lobes or lungs that are the site of chronic disease, usually with septic pneumonitis and bronchiectasis in patients inadequately treated in the early phases of the disease One-stage drainage is still indicated for patients who do not respond to antibiotic therapy and are too ill for major resection operations A real and continued decline in the incidence of lung abscess is the interesting climax of this story The main anxiety today concerns the abscess which is the sequel of staphylococcal pneumonia, in which the organisms are antibiotic-resistant

Etiology and pathology

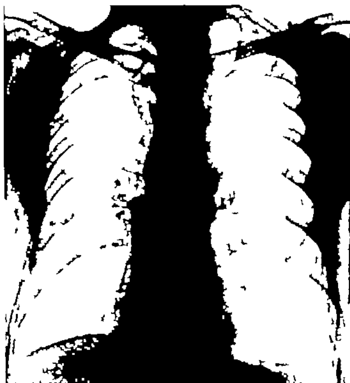
The location of lung abscess has a constancy capable of anatomical and pathological explanation Certain facts are established The right upper lobe is the commonest seat of acute lung abscess, followed by the right lower lobe as the next most frequent site If lung abscess was commonly a sequel of pneumonia or blood-borne infection this distribution would not occur, in blood-borne abscesses of the lung the distribution is often bilateral and multilobar (Fig 7 4) The usual cause of solitary lung abscess is undoubtedly bronchial embolism as shown by Brock, cancerous obstruction of a bronchus is the commonest cause, but foreign bodies must be remembered, as discussed later these causes indicate the need for diagnostic bronchoscopy in patients with lung abscess

The simple lung abscess is due to a bronchial embolus much smaller than a gross foreign body such as a tooth The embolus is of such a size that it is sucked into a segmental bronchus and may not invade a whole lobe, its nature is usually infected muco-pus, blood clot after dental extractions or upper respiratory operations such as tonsillectomy or adenoidectomy or from particles of septic "tartar" inhaled from the back of septic unscaled teeth The inhalation of foreign bodies may be undramatic, in the early stages the patient himself being quite unconscious of such a major embolism, even more silent is the passage of muco-pus, especially as it takes place in the patient while in sleep, or unconscious from a general anaesthetic

The predilection for lung abscess development in the posterior (posterolateral) segment of the right upper lobe and the apical segment of the right lower lobe is well explained by Brock as a postural phenomenon During sleep, particles of matter flow into the right main bronchus more readily than the left, and since most people lie on the right side the material will first incline to the opening of the posterior segment of the upper lobe as this drains towards the axilla, and the clinical fact that lung abscess most commonly affects the axillary portion of this segment supports this view After general anaesthesia many patients are nursed flat on the back until consciousness is regained and in this position the bronchial embolus, be it blood clot, muco-pus or dental debris, tends to flow into the apical segment of the right lower lobe The fact that post-tonsillectomy lung abscess used to develop most commonly in the right upper lobe is explained by the custom of placing such patients on their right side until the effects of anaesthesia had worn off

The postural explanation of the site of abscess formation could be developed more fully but one fact remains to be noted If lipiodol is placed at the back of the nose before sleep, a radiograph taken the next day shows that the oil has gravitated into the sites rendered





(a) (c)

FIG 7 1

(a) Consolidation and collapse of right lower lobe Pyrexia and offensive sputum ten days after extensive dental extractions.

This patient was referred as possible carcinoma of the right lower lobe for bronchoscopic examination. The tooth (Fig 7 1 (b)) was not noted on the radiograph

(c) A week after removal of tooth

Rapid clearing and re-expansion of right lower lobe



FIG 7 1 (b).—Tooth removed by bronchoscopy from right lower lobe



FIG 7 2.—Lung abscess in posterior segment of right upper lobe

There had been sudden pyrexial illness with cough fortnight before this radiograph was taken the dental condition was bad.

most dependent by the posture adopted by the sleeper as an example it will be found in the posterior segment of the right upper lobe if the subject, as is normal, sleeps lying on the right side (Amberson, 1937)

That the incidence of simple lung abscess is twice as common in men as women may be due to the greater male incidence of dental sepsis and the deeper amplitude of the breathing which may add to the dangers of inhalation

The easy access of particulate matter such as barium and iodized oil and of organisms to the lung bronchi under anaesthesia has been readily demonstrated in animals (Cutler, 1929) If the animals were maintained on planes of varied angles, substances placed in the mouth or nose could be recovered from the lungs if the head was on a plane above that of the body, quite irrespective of the depth of anaesthesia employed the aspiration effects were always abolished if the Trendelenburg position, even in its less exaggerated degrees, was used The clinical application of this to the human patient under anaesthesia indicates the constant vigilance required to correct dental and oral sepsis before operation and to take all means possible to prevent bronchial embolism, either by posture or by the use of cuffed intratracheal anaesthetic tubes or careful packing of the pharynx

Classification of lung abscess

Lung infection (pneumonitis) may resolve or proceed to suppuration or permanent structural damage such as bronchiectasis or fibrosis Usually the abscess is single but in blood infections may be multiple when it is due to specific infection such as the staphylococcus, streptococcus or Friedlander's bacillus Brock (1947) suggested a logical classification based on a group in which the causes are identifiable and on another in which the

TABLE I

R C Brock (1950)*

Identified causes (47 were due to bronchial carcinoma)	269
Obscure causes	94
	363

When the 47 abscesses due to carcinoma and the 94 cryptic cases were excluded, 222 patients were left for analysis

1 *Post-operative*	
Abdominal operations	41
Non-abdominal (these included 25 dental extractions and tonsillectomies)	39
	80
2 *Dental sepsis*	60
3 *Specific infections*	
Staphylococcus	21
Streptococcus	1
Friedlander's cases	2
Actinomycosis	2
	26
4 *Various causes* (including 16 upper respiratory infections and 13 lower respiratory infections)	56

* It is important to note that these cases were collected in the years before 1950 Since that date there has been a striking decrease of lung abscess in all clinics with the probable exception of staphylococcal ones

etiology remains debatable the primary cryptic type of abscess putting this classification to the test of exact analysis in 303 personal cases his findings were as shown in Table I on the previous page

It is of interest to note that a tooth or other inhaled foreign body in the bronchus was responsible for only 1 per cent of the abscesses whereas bronchial carcinoma was responsible for over 10 per cent

Such a classification is helpful because it indicates the need in early lung abscess for a full investigation which includes a careful history, clinical examination bronchoscopy and bacteriological studies of the sputum and blood

Perhaps trauma should be considered as an unusual cause of lung abscess In 1 000 examples of gun-shot wounds of the chest (d Abreu 1947) only 32 developed proven lung abscess Occasionally a pulmonary infarct becomes infected with development of a lung abscess

Decline in the incidence of lung abscess

Apart from post-operative lung abscess the decrease may be attributed to a lessened incidence of gross dental sepsis In spite of a continued decline in dental health fewer teeth are seen with gross deposits of tartar and though many more are edentulous the increased number of people with dentures has lessened the risk of bronchial embolisms from dental sepsis Coincident with this improvement in mouth hygiene is the decline in foetor of sputum both in lung abscess and bronchiectasis an odour that was commonly noted in the earlier days of lobectomy for bronchiectasis This foetor was largely due to secondary infection from organisms commonly associated with neglected oral sepsis The potential danger of oral sepsis is recognized in thoracic departments and special pre-operative dental care is practised before operations such as resection of lung tissue or oesophagectomy

The post-operative lung abscess whether following upper respiratory operations or laparotomy has become rare When the vogue existed for operating on the tonsils and accessory nasal sinuses in the sitting up position and before cuffed intratracheal tubes and careful packing off of the pharynx to prevent tracheo bronchial soiling became the routine lung abscess was not uncommon but increasing realization that after operations such as tonsillectomy blood was often found in the air passages if looked for through the broncho scope led to the adoption of preventive measures and this disaster is rare today The post-laparotomy lung abscess due to bronchial embolism of upper respiratory or bronchial muco-pus has been almost eliminated by the careful bronchial toilet either by suction or bronchoscopic aspiration and by the general use of active lower chest movements and the encouragement of the cough mechanism after such operation The remaining few that develop could be eliminated largely if bronchoscopic aspiration of retained muco purulent sputum were practised for lower lobe collapses that do not clear with postural drainage and by the encouragement of deep breathing and coughing

Unconsciousness or coma as a cause Pulmonary abscess is seen from time to time in alcoholic patients after a long period of unconsciousness or in patients who have been in coma as a result of narcotics diabetes trauma or following immersion in water The combination of such periods of unconsciousness with gross dental sepsis especially in elderly social derelicts in poor general condition is an occasional cause of abscess formation

The bacteriological aspect

In simple lung abscess the etiological factor being bronchial embolism or aspiration the infecting organisms may be of many different species the development of the disease

depends largely on the organisms which multiply distal to the segmental bronchial obstruction The ciliary action of the bronchial mucous membrane plays a part in ridding the unobstructed bronchus of infecting organisms and is aided by the normal cough mechanisms, in lobar or segmental collapse the upward transmission of organisms by the ciliary action towards the trachea is ineffective and they rapidly multiply The emboli are usually infected, e g blood clot, muco-pus, dental deposits, inhaled food or small foreign bodies and, as would be expected, the organism in a lung abscess consists largely of the pathogenic and non-pathogenic organisms commonly present in the mouth and upper respiratory system

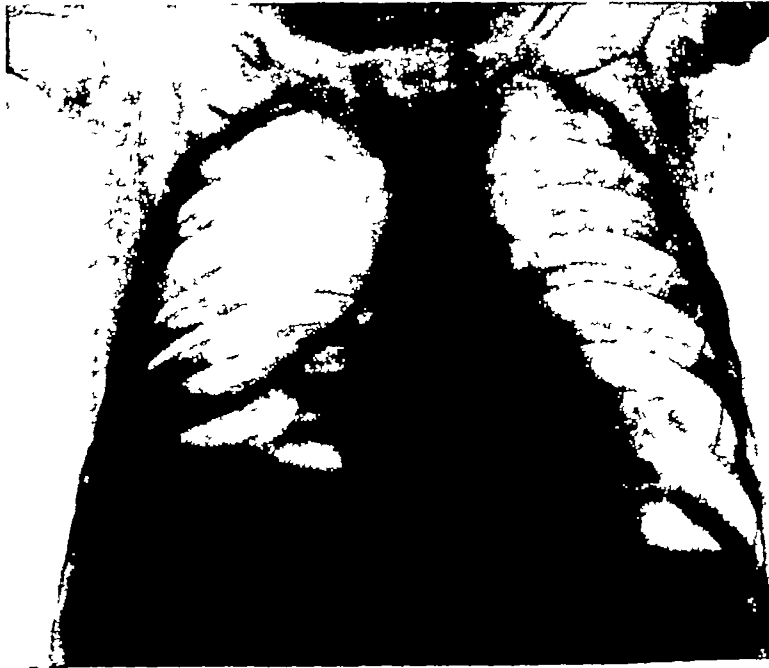


FIG 7 3 —Staphylococcal abscess in an infant simulating a cyst or local pneumothorax This disappeared completely on penicillin therapy Staphylococci were recovered from the sputum

Aerobic and anaerobic organisms flourish Pneumococci are the most frequent invaders, but staphylococci, streptococci (especially the viridans group), micrococci catarrhalis, fusiform bacilli, spirochaetes and Gram-negative bacilli are often present A pure culture of one organism is not usual and there is no specific agent, though the great increase in the range of antibiotics enables most to be attacked The putrid lung abscess probably depends on a large content of anaerobes combined with spirochaetes and the fusiform bacillus these have a capacity for causing rapid tissue death and in the putrid abscess a large central slough is common, most exceptionally the extension of this process may destroy a whole lobe (spontaneous lobectomy) Many of these organisms are sensitive to large doses of antibiotics there is evidence (Pile, 1950) that penicillin therapy when employed has often been along the lines of the classical dosage Pile believes this is inadequate and that at least two million units a day are required Since the spirochaetes are only secondary invaders and soon disappear when the abscess has either emptied into the bronchus or has been drained externally there is no case to be made for the use of arsenicals which in themselves may have depressing or toxic effects

Staphylococcal lung abscess or pneumonia Staphylococcal infection following a septicaemia is of special importance A pure staphylococcal empyema, usually seen in children, often indicates that a staphylococcal lung abscess has ruptured into the pleura But the most striking radiological appearances are seen in patients with multiple lung abscesses,

due to this organism these may be large in size (Figs 7 3 and 7 5) and tension in type often with obvious fluid levels The desperate appearance of the patient and of his X ray findings may suggest the need for drainage but this is an abscess where surgery is usually contra indicated they respond well to massive penicillin therapy if the organism which may be recovered from the sputum or blood is penicillin sensitive If it is resistant as proved by a study of the sputum content streptomycin and other wide range antibiotics should be used

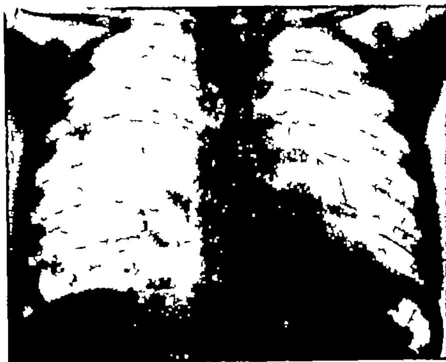


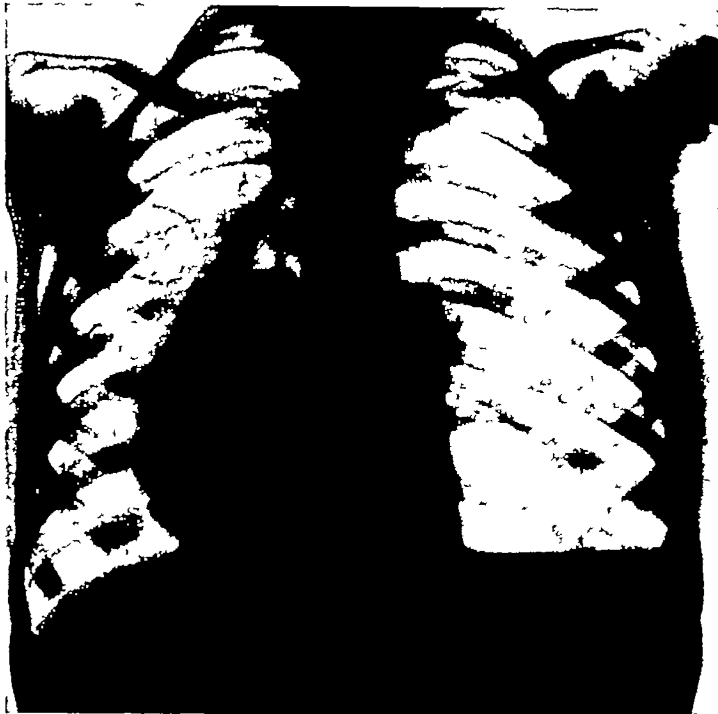
FIG 7 4 —Multiple staphylococcal lung abscess in the right lung in a child associated with a collapsed left lower lobe

Two of the abscesses are air-containing, but the one in the upper lobe is solid Staphylococci removed from the sputum. The right lung cleared completely under penicillin therapy

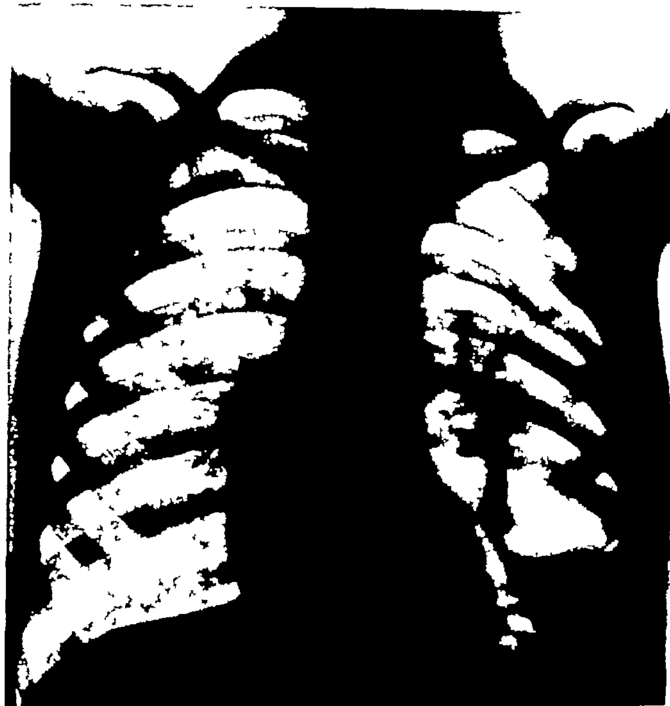
Occasionally these staphylococcal abscesses rupture into the pleural cavity adding considerably to the frightening appearances of the radiograph In spite of such a complication the condition may resolve completely with antibiotic therapy combined with paracentesis of the chest if fluid collects in the pleural cavity The radiographs shown in Fig 7 5 illustrate the course of such a patient in whom only one aspiration of the chest was practised penicillin was given parenterally in two daily doses of half a million units for six weeks If tension pneumothorax effects threaten life temporary water-sealed intercostal drainage by needle or tube is indicated

After considerable clinical improvement the radiological appearance of a cavity may persist it may be mistaken for a congenital cyst localized emphysema or partial pneumothorax

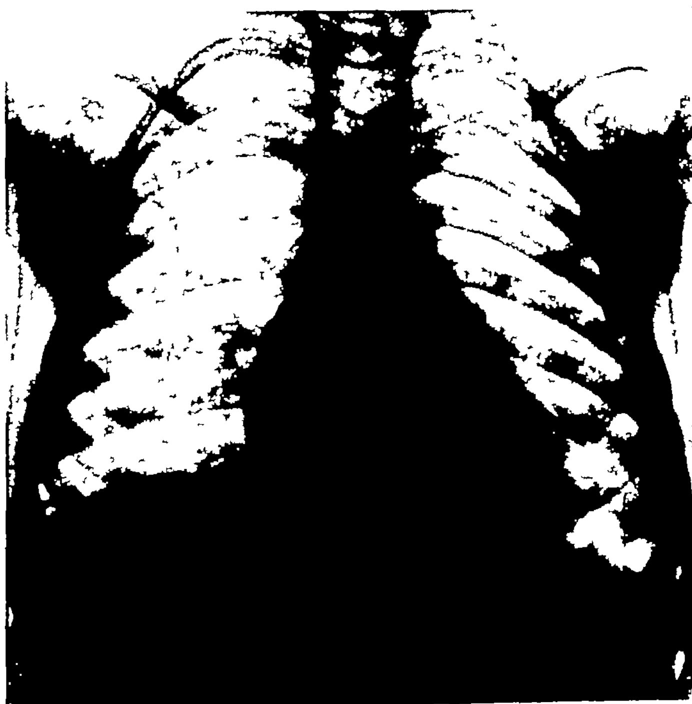
Rare infections Quite exceptionally lung abscess may be due to Torulosis due to *cryptococcus neoformans* Beck (1955) has reported this in England Histoplasmosis and coccidiomycosis are almost unknown in Britain Actinomycosis as a cause should always be remembered the diagnosis may be made after a long illness in which the streptothrix is discovered in the sputum Bates and Cruickshank (1957) have published their findings in 85 cases of thoracic actinomycosis and give a full account of the disease Of all



(a)



(b)



(c)

FIG 7 5

(a) A child of four years admitted with high pyrexia

There is a left pyo pneumothorax (staphylococci recovered from aspirated fluid) and collapse of the left lung A circular abscess cavity is also present in the right upper lobe

Treatment was by parenteral penicillin continued for six weeks In spite of the alarming radiological and clinical condition recovery was complete

(b) After three weeks

(c) After six weeks

the treatments available adequate penicillin therapy was undoubtedly the best They recommend 6 mega units of crystalline penicillin daily (2 mega units eight hourly while the patient is in hospital (6 weeks) followed by 600 000 units daily for another 6 weeks) They find that of 42 patients treated by penicillin (not always in the adequate dose they recommend) together with surgical measures such as drainage of empyema or excisions performed without a pre-operative diagnosis of actinomycosis 36 were alive at the time of their summary

Pulmonary coccidioidomycosis

As far as I am aware this condition is not met with in Great Britain but increasing numbers of cases are being reported in America (Cotton and Birsner 1950) As cavitation appears in this disease its differential diagnosis from lung abscess and pulmonary tuberculosis is necessary in areas where the disease is liable to develop and is best made by finding the characteristic spherules in the sputum In treating this condition Cotton and Birsner used pneumonectomy segmental lobectomy or local resection with decortication and decortication with thoracoplasty Melick (1950) has published an interesting report based on 109 excisions performed by different surgeons in the United States

Histoplasmosis of the lung

Infection of the lungs by histoplasma capsulatum is being increasingly recognized and studied the granulomatous lesion produced by the histoplasma may affect all areas of the body In the lungs no specific pattern can be described but unilateral or bilateral infiltrations may lead to a wrong diagnosis of pulmonary tuberculosis or neoplasm on the radiological appearances occasionally cavities form and these may be regarded as lung abscess A discussion of the subject has been published by Hodgson Weed and Clagett (1950) Arblaster (1950) reports its occurrence in England

Lung abscess that is not " simple

Major bronchial obstruction Gross obstruction of a lobar bronchus by a foreign body such as tooth or meat bone causes infected atelectasis more commonly than a lung abscess (see Fig 7 1) but the possibility of an abscess being due to an obstruction must always be realized and simple abscess unless cured rapidly after expectoration of its contents should not be treated without a bronchoscopic examination this is especially so in chronic lung abscess and many of these in men over the age of 50 are due to bronchial carcinoma and serious errors will follow the neglect of bronchoscopic examination

Carcinoma of the lung apart from producing a lung abscess distal to its blocking effect on a bronchus may break down in the centre and give an appearance of lung abscess The tumour that breaks down is usually a squamous epithelioma on radiological examination the walls of such an abscess are thicker than those seen in the true pyogenic state or a tumour mass is visible within the cavity

Pulmonary infarction Post-operative pulmonary infarcts may go through a phase of septic pneumonia leading to lung abscess and in addition to any measures used in the treatment of the thrombosis such as heparin or other anti-coagulants or ligation of the iliac vein or of the inferior vena cava chemotherapy should be instituted in all patients who survive a pulmonary embolus

Septic embolism Before the era of effective chemotherapy and the use of antibiotics pyaemia was not uncommon in many conditions such as osteomyelitis or peripheral sepsis Maxwell (1934) in a series of 116 multiple lung abscesses found that 62 had followed septic

conditions elsewhere The abscesses will be multiple in most instances Of special interest to thoracic surgeons are those occasionally associated with mycotic aneurysms of branches of a pulmonary artery in patients with infected duct arteriosus

Lung abscess associated with subphrenic abscess The natural history and treatment of





Fig 7 6 Fig 7 7

Fig 7 6—Squamous carcinoma of right upper lobe with a small air-filled cavity (Pneumonectomy) Note the solidity of the walls

Fig 7 7—Carcinoma of left upper lobe in a man of 52 which has broken down into an abscess Diagnosis confirmed by bronchoscopy and pneumonectomy

this is discussed in Chapter 27 The abscess more usually develops as a complication of collapse of a lower lobe than as a result of direct extension of the subphrenic inflammation across the diaphragm A noticeable exception to this is the spread of hepatic amoebic abscess (see p 595)

Complications of lung abscess

These may be local or general

Local complications The spread of the local process in abscesses that do not resolve naturally or with the aid of partial drainage and antibiotic therapy often produces a permanent bronchiectasis in the lobe affected

Increased tension within an undrained abscess may cut off the blood supply sufficiently to cause lung gangrene with the production first of a large slough followed later by death of the whole lobe In a few exceptional examples the whole lobe is sequestrated and at operation for empyema has been lifted out as a large necrotic mass (spontaneous lobectomy)

Unless the abscess disappears rapidly after the sudden expectoration of pus, a valvular

mechanism often develops at the site of rupture into the bronchus the communications with the bronchus may be multiple and bulge into the abscess space As in tuberculous cavities air can enter the space more easily than it can escape because the fistulous openings are oedematous and in the normal process of expiration become narrowed this is accentuated by the inflammatory thickening of the bronchial fistulae This mechanism is illustrated by the specimen shown in Fig 7 9 of a right upper lobe removed for a lung abscess which shows the pouting bronchial openings into the cavity

The rupture of an abscess into a pleural cavity is a serious complication and is the usual

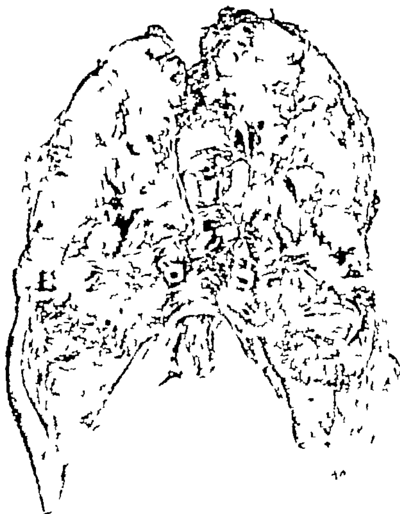


Fig 7 8 —Operation specimen
Extensive structural alteration round a chronic lung abscess cavity note also the dense thickening of the visceral pleura.

cause of putrid empyema Local extension to the pericardium is unusual but may cause septic pericarditis

General complications In addition to general toxaemia and quite rarely of amyloid disease septic thrombophlebitis may cause a cerebral abscess or meningitis and the recognition and prompt treatment of this condition is important as there now exists hope of recovery for these previously doomed patients The neurosurgical treatment of metastatic cerebral abscess by antibiotic therapy diagnostic ventriculography exposure and aspiration of the effusion and later excision of the encapsulated infection is followed if possible by resection of the affected area of the lung and notable recoveries have been published after this attack on thoracogenic cerebral abscess (Pennybacker and Sellors 1948)

The development of neurological signs pointing to a cerebral abscess is occasionally the result of a cortical cerebral venous thrombosis and this may be seen at the cerebral exploration J M Small has diagnosed this in four of my patients with suppurative lung conditions and all recovered

Clinical features

History Patients who develop an abscess while in hospital have usually had surgical operations on the upper respiratory system, the mouth or the abdomen followed by an uneasy convalescence In this group and in those who commence their illness at home the story is rarely a typical one Malaise, a commencing rigor and a high sustained pyrexia often



Fig 7 9



Fig 7 10

Fig 7 9 —The interior of a lung abscess from a lobectomy specimen showing the inadequate drainage through multiple pouting bronchial fistulae

Fig 7 10 —Abscess of left lung in a man of 59 this followed a pulmonary embolus from a thrombosed calf vein Bronchoscopy was negative and resolution and cure followed chemotherapy

precede cough and expectoration , pain in the chest is usually localized to the intercostal space overlying the affected segment If the first sputum expectorated is foetid in odour a diagnosis may almost be made on this alone This symptom may be preceded by a bad taste in the mouth and the breath may be offensive before there is any actual sputum The high temperature the sudden prostration and the pleural pain often lead to a diagnosis of "pneumonia ", but in the early days of lung abscess the short ineffective cough is usually absent and dyspnoea is not a marked feature Haemoptysis is frequent and often precedes by a few hours the onset of sputum production The patient may be referred for an opinion as to the causation of an unexplained pyrexia in infants and children this is often so with multiple staphylococcal abscesses and pyrexia of unknown origin may be the first indication that a lung abscess is in fact present The sudden expectoration of a large quantity of pus is often the most helpful feature but as this may follow the intrabronchial rupture of an

unsuspected empyema it is not diagnostic Once the active phase is over rapid development of clubbing of the fingers together with pain and swelling of the larger joints is not infrequent

Physical signs As in all chest disease the absence of obvious signs is not of diagnostic significance as the segment affected may be inaccessible to accurate percussion or auscultation A sign of value is the discovery of a tender area when the intercostal spaces overlying the abscess are palpated this tenderness is often fleeting being due to the over lying pleuritis which causes adhesions to develop with greater rapidity than in any other intrathoracic disease Diminished chest wall movements an increase of tactile fremitus and slight flatness to the percussion note may be detected followed by the presence of bron chial breathing over a strictly localized area When cavitation has developed amphoric breathing may be heard but this is not usual. Râles may be audible but are of little significance or help The greatest aid to diagnosis is the combination of obviously severe illness with pyrexia and chest pain that leads to the taking of radiographs of the chest

Sputum examination The sudden appearance of purulent sputum in a previously healthy patient is significant and its naked eye examination is most helpful Further examination includes a search for predominant organisms for elastic fibres (indicative of lung destruction) and for malignant cells in case the cause is a bronchial neoplasm

Radiology of lung abscess

Perhaps the commonest error is to expect a fluid level in lung abscess such levels are not seen in the early stages when the shadow cast has no more characteristic feature than consolidation or collapse of a broncho pulmonary segment (Fig 7 2) but even the discovery of this in patients with a history suggestive of lung abscess is important although other lung lesions may produce similar appearances

If the radiograph demonstrates a cavity with a fluid level it is still necessary to consider a tuberculous process a lung abscess due to neoplastic bronchial obstruction or an infected lung cyst

Differential radiological diagnosis

Radiological appearances vary enormously depending largely on the presence or absence of a fluid level. When a solid infiltration is present the diagnosis from lung carcinoma suppurative pneumonia and tuberculosis may be impossible on radiological grounds and every help such as history sputum examination and bronchoscopy will be required. In the middle-aged and elderly carcinoma of the lung is more often responsible for puzzling lung opacities than lung abscess and exploratory thoracotomy is often the final diagnostic resource if improvement with penicillin therapy is not rapid Exceptionally a lower accessory lobe may provide confusion (Fig 7 11)

When a fluid level is present differentiation from empyema with broncho pleural fistula and from hydatid cyst disease as well as congenital accessory cyst is necessary in addition pulmonary neoplasm and pulmonary tuberculosis need to be excluded Lung abscess is usually a segmental lesion and the recognition of this fact helps greatly in differentiating from the empyema with a broncho pleural fistula The difficulty is chiefly seen when the empyema is of the interlobar type In empyema with a broncho pleural fistula the apex of the empyema cavity is usually triangular when lateral radiographs are studied (see Fig 6 4)

In differentiating a lung abscess from a breaking-down peripheral carcinoma of the lung the latter has thick walls an extreme example of this is given in Fig 7 6

Tomography may help in showing a neoplastic obstruction in a bronchus leading to abscess cavity but this can be provided also by granulomatous tissue causing bronchiectasis, lipiodol bronchography is of little value as the oil will not flow into the cavity except in a chronic abscess of long duration lined by squamous epithelium As mentioned earlier bronchoscopy is of the greatest value in detecting or excluding bronchial tumours or foreign bodies



FIG 7 11 —A right lower accessory cyst in a woman of 32 with a long history of cough and sputum At operation the condition was typical of lower accessory cyst with an abnormal artery supplying it from the abdominal aorta

Treatment of lung abscess

The interventions required for lung abscess due to foreign bodies and those associated with neoplasm of the bronchus have been indicated (see p 133)

As soon as a simple lung abscess has been diagnosed treatment by appropriate postural drainage and chemotherapy is instituted Two million units of penicillin or other appropriate antibiotic should be given daily and continued long after the general condition has improved, six weeks being an arbitrary period during which antibiotic therapy is required Sensitivity of the prevalent organism should be assessed constantly If the pyogenic organisms are penicillin insensitive, tetracycline in full doses is used , this is of especial value if Gram-negative organisms are considered to be responsible in part for the illness The treatment of tension pneumothorax in staphylococcal abscess has been described on page 131

With this regime few abscesses require external drainage and the change in outlook has been discussed previously If the patient has been diagnosed after the lapse of several weeks or has failed to respond to conservative measures treatment of the abscess by segmental resection or lobectomy is often indicated

Surgical drainage for lung abscess. Quite exceptionally a lung abscess is treated by simple open drainage which is reserved for seriously ill patients who are deteriorating

under conservative measures and yet would probably fail to survive resection. Because lung abscess is a peripheral lesion which rapidly causes adherence of the visceral to the nearest area of parietal pleura access to it through the bed of a resected rib is easy and safe unless it is in an unusual site adjacent to the diaphragm or mediastinum , although ' peri pheral in the true sense of the word such abscesses are inaccessible and whenever possible should be treated by resection rather than by drainage In the more usual sites the abscess is adherent to the chest wall at a rib site that can be estimated accurately by a study of the radiographs in the postero-anterior lateral and oblique views

The operation This is performed under local anaesthesia after a meticulous radiological localization of the abscess and a portion of one occasionally two ribs resected sub periosteally If the incision has been made exactly over the site of the abscess a cautious incision through the periosteal bed will reveal pleural symphysis and the abscess can be opened immediately Two-stage drainage by which the evacuation of the abscess is delayed until adhesions have been produced by means of packing leaves a very ill patient still with unevacuated pus and hampered by a painful wound which inhibits the act of coughing when this method was in common use it was not unusual for the patient to die before the second stage could be completed If however the incision has been misplaced and the pleura is clearly free it must not be opened Two alternatives are possible either another rib is resected in the correct site or the wound is packed for a few days to produce a safer pleural adherence

Before the adherent lung is incised a large-bore needle mounted on a glass syringe containing a little sterile water is used to explore the abscess for the presence of pus or air obviously this should not be used until the rib has been resected as blind needling may be as dangerous here as in patients with subphrenic abscess (see Chapter 27) with every possi bility of producing an empyema

The abscess cavity must be opened freely and all loculi thoroughly explored bleeding in the compressed oedematous lung tissue is slight When the cavity has been well opened it should be packed lightly with gauze which is replaced a few days later by a soft open drainage tube

SUPPURATIVE PNEUMONIA

(Suppurative pneumonitis)

The truth about pneumonitis however is that so many different people put a different content into the term that the very word breathes confusion and muddle (Coope 1946)

Every thoracic surgeon sees patients who are ill after a pyrexial lung illness followed by cough perhaps with haemoptysis and continued expectoration in whom the radiograph shows spreading areas of consolidation crossing from one lobe to the other with areas of cavitation The cavities are usually small the consolidation considerable and the clinical course is downhill, with death some months after the onset of the illness The absence of tubercle bacilli led to the older description of non tuberculous consumption

Probably the diagnosis of suppurative pneumonia should not be made until the lobe or lung has been submitted to actual pathological examination either after excisional surgery or in the autopsy room or unless complete clinical resolution has followed for many patients so diagnosed in life have a bronchial obstruction usually due to carcinoma though occasion ally to a foreign body but the condition undoubtedly exists Whereas lung abscess is

typically a segmental disease, suppurative pneumonitis keeps to no such rigid boundaries often spreading from segment to segment or lobe to lobe The main difficulty in the study of these pulmonary infections is that the evidence is largely radiological in patients who survive, or who do not undergo surgical resections

" Pneumonitis " of surgical interest

As long ago as 1866 (Austin Flint), the word " pneumonitis " was employed as a generic term to include all examples of acute and chronic pneumonia, but this choice of terminology gained little favour Acute lobar pneumonia and tuberculous disease are rigidly excluded from this group today Radiologically an area of consolidated lung parenchyma in patients in whom the diagnosis of neoplasm tuberculosis, lobar or virus pneumonia has been excluded as far as possible may be labelled as " pneumonitis " to differentiate it from atelectasis



FIG 7 12 —Radiograph of a woman of 52 who had suffered from cough, expectoration of purulent blood-stained sputum and pyrexia

The patient was referred to hospital as ' unresolved pneumonia ' At bronchoscopy a mutton bone embedded in granulation tissue was removed from the right lower lobe

The continued use of the term is only justifiable if it indicates uncertainty as to the true etiology and pathology of the condition Most patients with " pneumonitis " have in fact bronchial carcinoma or lung abscess but a small group, raised in incidence after epidemics of influenza, undoubtedly have a subacute, chronic or suppurative infection of the lung parenchyma which persists, causes continued illness and is sometimes fatal If the chests of sufficient people who have suffered from the common cold or influenza are radiographed, a reasonable proportion show opaque areas of considerable size in the lung parenchyma, the natural history of these opacities is that they disappear rapidly leaving no trace of their original presence but in a few the areas enlarge and the clinical condition deteriorates No specific organisms have been incriminated as the cause of this persistent lung infection pathological examination after death or resection usually shows a condition that might well be described as a coalescing suppurative bronchopneumonia

A particularly serious type of " pneumonitis " has been described by Sellors Blair,

Houghton, Thompson and Pryce (1946) They recorded 27 patients with a spreading inflammatory process in the lungs which invaded different areas of the lungs and usually cavitated 10 died The patients were ill and pyrexial with copious expectorations occasionally foetid The only satisfactory treatment of the patients who were studied over a long period to discriminate them from lung abscess pulmonary tuberculosis or neoplasm appeared to be excision which often involved pneumonectomy because of the widespread character of the disease These authors were not able to establish any definite etiology and called the state ' spreading suppurative pneumonitis The disease was noted chiefly in middle-aged men It is a rare condition today

Persistent lung infection requiring surgery

A less dramatic but none the less serious group of patients are those with radiological appearances of pneumonitis that accompany general ill health with constant expectoration of purulent sputum often with haemoptysis In the middle aged group although bronchoscopy fails to detect a tumour the assumption (usually a wise one) is that a carcinoma is present and thoracotomy reveals a chronically infected lobe which is resected

In younger patients chronic pyogenic infection of the lung not easily classified as lung abscess may persist in spite of all treatment and require surgical excision Such patients may start with a pyrexial illness the differential diagnosis being epituberculosis or pneumonia The expected resolution of these processes may fail to take place pyrexia persists and sputum production increases The condition is rare

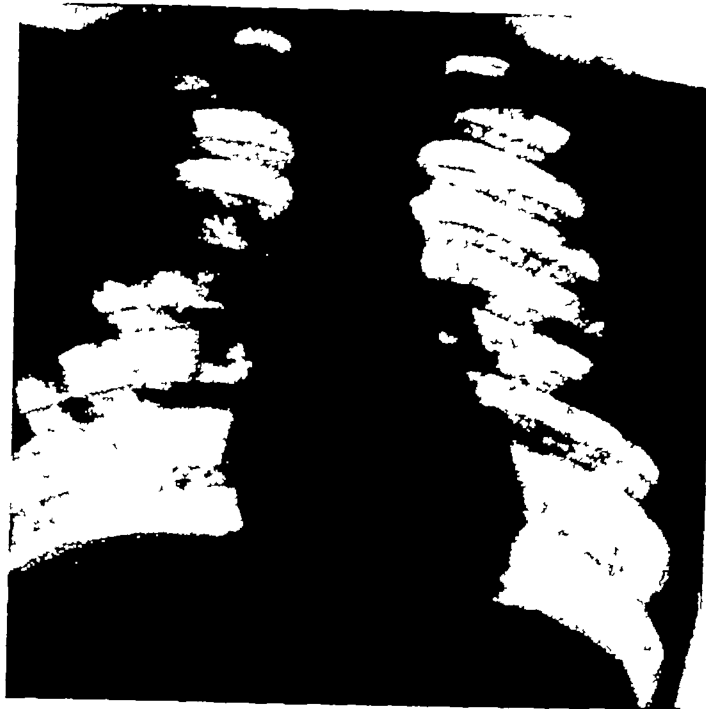
A boy of 14 was admitted to hospital with the diagnosis of epituberculosis (see Fig 7 13) He had severe cough with little sputum and continued pyrexia (100–101) The Mantoux reaction was negative and remained so for the next 11 months during which period the amount of sputum steadily increased (up to four ounces a day) The result of persistent search for tubercle bacilli remained negative, the sputum containing a mixed flora At bronchoscopy the right upper lobe was red and full of thick pus no caseating material was present and there was no evidence of bronchostenosis to support a diagnosis of atelectasis of the right upper lobe due to bronchial occlusion He was ill toxaemic and losing weight The right upper lobe was therefore resected and he made a complete recovery

The whole of the upper lobe was replaced by inflammatory tissue which contained multiple abscess cavities, involving all segments. The diagnosis of suppurative pneumonitis or pneumonia therefore seems acceptable

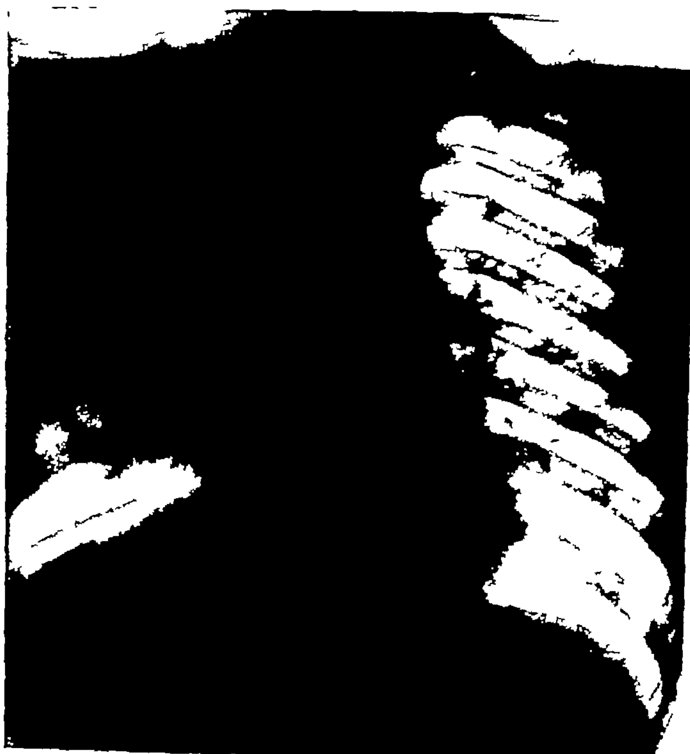
Nicholson (1950) has reviewed the subject of suppurative pneumonitis in considerable detail He applies the term suppurative pneumonitis to those patients in whom an inflammatory consolidation of the lung proceeds in part or in whole to suppuration Pneumococcal pneumonia does not proceed to suppuration in the way that infection with the staphylococcus or Friedlander s bacilli does * If carcinoma is excluded as a cause of the suppurative pneumonia there is a residue of patients with non-specific chronic suppurative pneumonitis Their disease probably started as the result of aspiration of upper respiratory muco pus after such aspiration consolidation may develop which clears rapidly or the condition may persist as chronic suppurative pneumonia or proceed to further abscess formation.

The chronic suppurative pneumonia group may develop abscess cavities that come and go These patients may respond to treatment with penicillin and sulphamethazine but if chronic structural changes such as bronchiectasis or cavities persist the condition is

* Friedlander s pneumonia passes from an acute to a chronic destructive process unless adequately treated by streptomycin chloramphenicol and sulphadiazine The disease is probably due to aspiration from the naso-pharynx (Amberson 1954)



(a)





(b) (c)

Fig 7 13

(a) Radiograph of a boy of 14 years the condition was regarded at first as epituberculosis, but the Mantoux reaction was negative

(b) Eleven months after radiograph shown in Fig 7 13 (a) A P view Obvious progression of the inflammatory process

(c) Lateral view of chest Mantoux still negative Suppurative pneumonia See text

dangerous in addition to being a cause of continuing chronic ill health The best hope of recovery lies in resection of the diseased lobe or lung The surgeon therefore who resects a lobe or lung with chronic suppurative pneumonia as occasionally happens when he thinks he is removing a carcinoma often saves the patient from chronic ill health or death. Chronic suppurative pneumonia is a serious disease and is fundamentally a surgical problem. Before surgery is undertaken a complete clinical survey including bronchoscopy must be completed the commonest errors being to classify a patient as suffering from pneumonitis when the condition is due to tuberculosis bronchial carcinoma or foreign body obstruction

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CHAPTER 8

BRONCHIECTASIS

Bronchiectasis is an anatomico-pathological description of dilated bronchi but it is also used widely as a clinical term indicating that the dilatation is accompanied by infection, sputum production and frequently haemoptysis At certain phases it is curable in many patients without apparent loss in respiratory efficiency Surgery has established itself as a good form of treatment for many patients, and apart from a few examples of natural resolution (reversible or pseudo bronchiectasis) is the only hope of permanent cure, but surgical excision is by no means capable of being applied, nor is it indicated, in all instances

In the last twenty years great progress has been made in the recognition, pathological study and surgical treatment of bronchiectasis It is unusual now to see advanced disease represented by patients with foetid breath, who coughed up huge quantities of foul sputum and who died from toxaemia, exhaustion and cardio-respiratory failure or from the complications of lung abscess, putrid empyema or cerebral abscess Early diagnosis in childhood and adolescence is now followed by surgical excisions or important conservative measures capable of averting the worst features of the natural history of the disease It must be noted that many patients with bronchiectasis discovered by routine X-rays have few or no symptoms

The symptoms may remit, depending on factors such as climatic conditions and recession of naso-pharyngeal infections The pathological picture once established is irreversible and surgical excisions are often practised at some stage, unless too widespread a distribution makes this impossible The best age at which excision should be practised remains unestablished, lobectomy in children is often deferred until they are old enough to co-operate, especially in the post-operative phase The operative mortality rate between the ages of 8 to 25 years is less than 1 per cent *

Although the disease is becoming increasingly recognized, many patients with a history of chronic cough and repeated pneumonia escape diagnosis because a radiological examination has been omitted The physical signs of chronic bronchitis and of bronchiectasis as detected by the stethoscope may be similar, but the radiological appearances, especially with bronchographic visualization after the introduction of lipiodol, provide striking contrasts

Etiology and pathology

In the early surgical literature dealing with the condition, a congenital origin was attributed to many examples of bronchiectasis This supposition has not been upheld and usually the condition arises from the combination of bronchial occlusion (often temporary) and infection Many of the patients give a history of lung symptoms in early childhood following diseases such as pneumonia, whooping cough or measles Often the disease has followed a known incident such as lobar or segmental collapse, and is not infrequent after a primary tuberculous infection In a children's hospital there is available evidence to indicate that radiographs taken before the onset of serious symptoms reveal normal lung

* In the five years (1950–1954) 312 resections for bronchiectasis were carried out with three deaths at the Queen Elizabeth Hospital, the Children's Hospital and Hill Top Thoracic Surgical Unit, Birmingham, 80 of these were bilateral resections and in the whole series 170 had bilateral disease

patterns Bronchiectasis without atelectasis however is commoner the dilatation is cylindrical or mildly saccular and patchy It may result from an inflammatory partial stenosis of swollen bronchi or bronchioles The lung tissue beyond the stenosis may remain aerated as the result of an air drift through the collateral air circulation of Van Allen The phenomenon has been well explained by Churchill (1949)

Congenital bronchiectasis

The left lower lobe in particular may fail to expand after birth, which may explain why this lobe is the one most commonly involved in bronchiectatic changes but even such bronchiectasis should be regarded as acquired The term true congenital bronchiectasis should be restricted to a few examples of cystic disease single or multiple to dissociated lung masses or cysts and possibly to the Kartagener complex Since congenital cystic

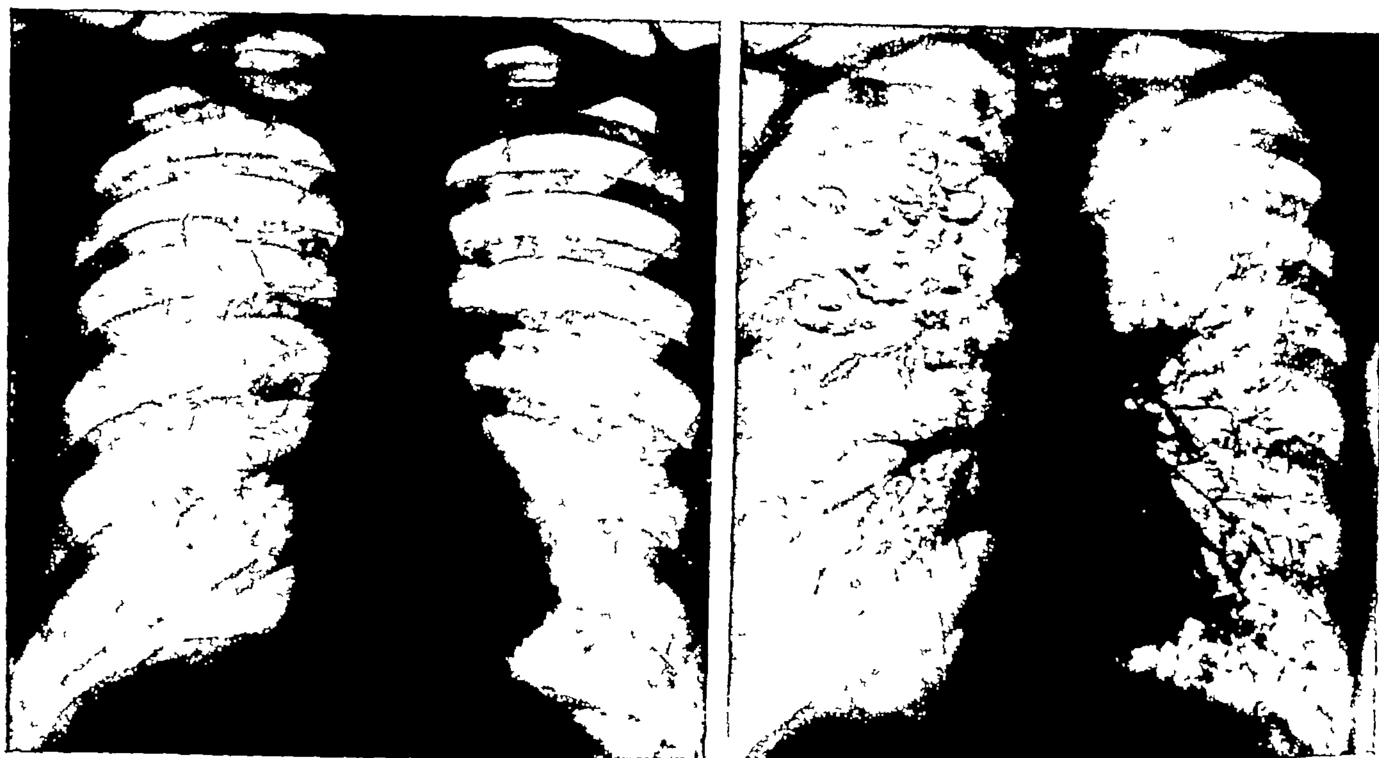


FIG 8 1 —Acquired saccular bronchiectasis.
The plain radiograph shows cystic spaces in the right lower and middle lobes The condition was due to an inhaled grass stalk discovered during the course of a right lower lobectomy

disease is not really bronchiectatic it has been considered elsewhere in further detail (see p 23)

Congenital cystic disease may be diagnosed radiologically when in fact the condition is acquired such a mistake was frequent in earlier days when the radiographs such as those shown in Figs 8 1 and 8 2 were studied Fig 8 1 is the radiograph of a child of 2 who had a constant cough and was severely toxic The circular spaces seen in the right middle and lower lobes are due to saccular bronchiectasis as demonstrated by the bronchogram Lobectomy was carried out at this young age because of continued deterioration and the lobectomy specimen showed the right lower lobe bronchus to be partially occluded by a thick grass stalk

A honeycombed upper lobe in adults used frequently to be labelled as "congenital cystic disease", undoubtedly infants have been born with honeycomb lungs in which the evidence favours a congenital origin, but most of the adult patients previously regarded as having congenital cystic disease were examples of acquired saccular bronchiectasis, due to upper lobe stenosis, the result of compression by enlarged tuberculous glands or actual bronchial disease Figs 8 2 (*a*) and (*b*) represent such a type, the soap-bubble appearance on the straight radiograph and the confirmatory bronchogram are not evidence of congenital



(*a*) (*b*)

FIG 8 2

(*a*) Radiograph of a woman of 30 complaining chiefly of haemoptysis
The soap bubble appearance of the right upper lobe is characteristic of what previously was called "congenital cystic disease"

(*b*) Bronchogram of the same patient
Upper lobectomy revealed partial upper lobe stenosis due to old healed tuberculous glands

origin, the lobectomy specimen from this patient had the features of acquired saccular bronchiectasis due to a compressed right upper lobe bronchus, the result of healed tuberculous glands

In another patient a left lower lobectomy was followed by collapse of the upper lobe Over the course of several months this lobe showed cystic changes radiologically, a residual lobectomy was performed (Fig 8 3)

Congenital malformations such as solitary cysts or dissociated lobes or duplications of the foregut (see p 23) are not infrequently complicated by bronchiectasis in the surrounding lung tissue, possibly as a result of infection in the misplaced tissue or from pressure on neighbouring air tubes into which fistulae may form

The bronchiectasis of the upper lobe above the "dissociated" lobe, illustrated in Fig 8 4, was undoubtedly acquired as a complication of the associated congenital defect

The present tendency is to regard most examples of bronchiectasis as being acquired and only a few cases of congenital cystic disease can be accepted with confidence In the

radiological diagnosis of circular spaces in the lung perhaps the term "honeycomb lung" is more satisfactory than that of "cystic disease" Such appearances may be caused by acquired bronchiectasis true congenital cystic disease or emphysematous disease



Fig 8 3



Fig 8-4

Fig 8 3 —This left upper lobe provided a radiograph with bubble appearance of cystic disease

A left lower lobectomy had been followed by a small empyema round the bronchus stump either as result of bronchial embolism from this abscess or because of upper lobe stenosis d t the enlarged glands which are seen i the photograph, the left upper lobe became cystic Lobectomy specimen showing acquired saccular bronchiectasis The probe is in the stump of the lower lobe bronchus.

Fig 8-4 —A large lower lobe cyst complicated by upper lobe saccular bronchiectasis.

During the pneumonectomy an abnormal systemic artery derived from the abdominal aort was seen entering the area of the cy t of the lower lobe which is congenital in origin.

The Kartagener complex

In 1933 Kartagener described a group of patients with bronchiectasis who had transposition of the viscera detected by discovery of dextro-cardia associated with congenital abnormalities of the para nasal sinuses notably absence of the frontal ones Just under half of these patients have symptoms of cough in the first ten years of life and a quarter develop them in the next decade Adams and Churchill (1937) pointed out that the bronchiectasis in this type of patient had the characteristics of the acquired condition and later Churchill (1940) was able to report two patients with only two features of the trilogy (dextro-cardia and absent accessory nasal sinuses) who had no bronchiectasis He described the moist exaggerated bronchial secretions of these patients who were carefully treated with chemotherapy when respiratory infections developed and he hoped that this careful management might prevent the development of bronchiectasis which is probably

acquired secondarily in the so-called Kartagener syndrome and is not truly a congenital lung condition.

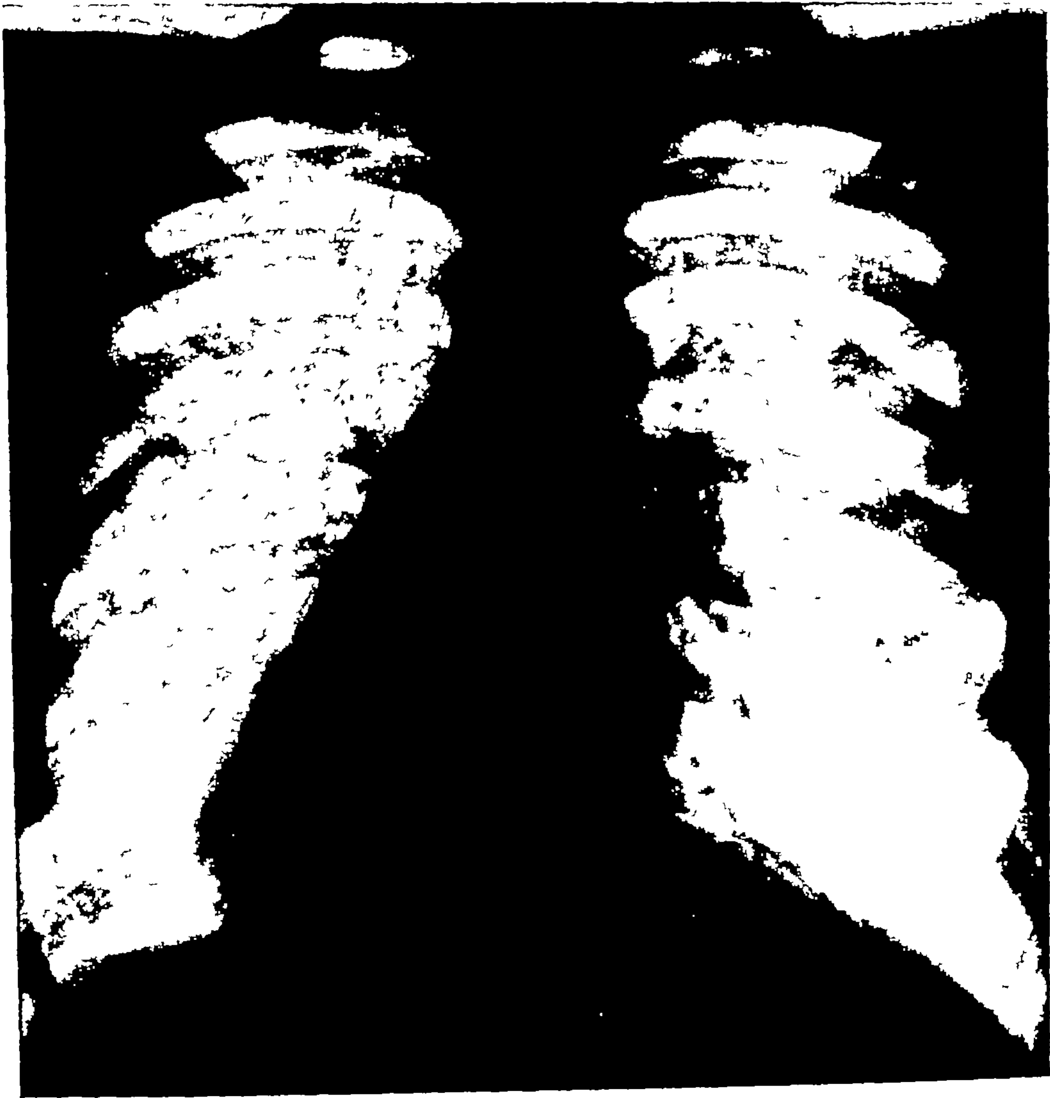


FIG 8 5—The Kartagener complex
A boy of 8 with dextro cardia the left middle lobe and the right lingula have been resected for bronchiectasis

The mechanism of acquired bronchiectasis

The common etiological factors are probably bronchial occlusion and the continued presence of infection in the bronchial wall itself If the affected bronchus is occluded by foreign body material or intrabronchial plugs of tenacious muco-pus which are not easily expelled or removed, or if the bronchial wall itself is stenosed as in broncho-stenosis produced by tuberculous granulation tissue or neoplastic tissue or by the pressure of extrabronchial lesions such as glandular hypertrophy, pyogenic or tuberculous, fully developed bronchiectasis may ensue Beyond such blocking agents the air within the affected lung, lobe or segment becomes absorbed and the alveolar walls adhere to each other, the bronchi, because of the nature of their cartilaginous wall, do not collapse but perhaps the intrapleural sub-atmospheric pressure encourages their dilatation especially if weakened by acute inflammatory changes and distension by retained exudates, inflammatory changes develop

rapidly as can be seen when a lobe collapses massively after an abdominal operation when pyrexia and severe malaise develop almost immediately

The commonest occluding mechanism is probably provided by enlarged peri bronchial lymphatic glands or the lodging in the bronchi of thick muco-pus The latter combined with viral infection may explain those common examples of bronchiectasis that develop in children after they have suffered from the evil combination of measles and whooping cough But bronchiectasis is seen after foreign bodies have been left because of their unsuspected presence and in lobes or lungs rendered airless by obstruction due to growth (Fig 8 6)



Fig 8 6—Gross cystic bronchiectasis of the right lower lobe due to a bronchial carcinoma which obstructed the lower lobe bronchus.

Pneumonectomy specimen Courtesy of Dr Cruickshank, Pathology Department Hill Top Hospital

Many examples of bronchiectasis have their origin in tuberculous disease in children this may be due to compression of the bronchus by enlarged tuberculous glands or by actual tuberculous endo bronchitis The best example of this etiology is seen in middle lobe disease in this common combination the middle lobe collapses and a careful study of the radiograph often shows a tuberculous complex in the right lower lobe Not all of these lobes re-expand and if the obstruction persists bronchiectasis is inevitable and may not cause symptoms such as haemoptysis or cough until later life

Roberts and Blair (1950) have presented interesting and convincing views of the etiological factors of bronchiectasis following tuberculosis in children Of 400 examples of primary lung tuberculosis 77 (19 per cent) had later collapse of a lobe segment or lung 37 of these were subjected to bronchography and bronchiectasis (often symptomless) was found in 34 In several of these patients during bronchoscopy under general anaesthesia

the intrapleural pressures were measured and showed no increase in the negative intrapleural pressure Roberts and Blair believe that the bronchi dilate under the increased intra-bronchial pressure provided by distension, the result of retained mucus, caseous material or secondary infection of the retained mucus beyond the site of the bronchial obstruction The important application of their finding is that a Mantoux test should be made in all children with collapse of the lung or bronchiectasis and surgical excision if recommended should be delayed for two years, streptomycin being given to cover the operative procedure if a tuberculous etiology is proved or suspected This cautious approach applies only to true bronchiectasis and not to the lobe changes which accompany a "complicated" primary tuberculosis which Dillwyn Thomas has shown sometimes requires excision of glands



FIG 8 7—A typical example of middle lobe obstruction due to tuberculous glands, no lipiodol has entered the middle lobe

The lobe failed to re expand after a year's conservative waiting because of constant cough and occasional haemoptysis the lobe was removed with uneventful convalescence gross bronchiectasis was present in the middle lobe, the bronchus of which was occluded by healed tuberculous glands

There is a good deal of evidence (Negus) that bronchial obstruction hampers the beneficial effects of the ciliary action of the bronchial mucous membrane below the site of the obstruction and the loss of this function prevents the removal of bacteria from the bronchus affected and infection rapidly develops

Bronchiectasis associated with para-nasal sinus infection

As many patients with bronchiectasis have para-nasal sinus infection it is important to consider the implication of this combination It is clear that major rhinological operations almost invariably fail to improve the state of the upper respiratory passages in the presence of bronchiectasis and yet notable improvement may follow successful resections of the diseased lung area The constant bouts of coughing may infect the nasal sinuses

and induce or aggravate the state of sinusitis Riggins (1941) has considered this point carefully in 100 cases of bronchiectasis 30 had chronic sinus disease and 20 of these had been known to have had bronchiectasis from several months to several years before they developed the nasal disease He indicated also that most patients with bronchiectasis had that disease in their first decade of life whereas the association of para nasal sinus disease with the lung condition developed most frequently in the second decade of life These figures suggest that sinus infection may be secondary to or aggravated by the bronchiectasis

Brock (1950) favours the postponement of major nasal operations until after the lung has been operated upon when surgery for bronchiectasis is indicated

This simplified version describing collapse and infection as the main etiological factors in bronchiectasis fails to explain the peculiar distribution of the disease in so many patients Lung abscess is due to bronchial embolism of infected material in most instances and affects those areas of the bronchial tree most vulnerable to aspiration from above namely the posterior segments of the right upper lobe and the apical segment of the right lower lobe In bronchiectasis however the lower lobe and the lingula of the left side and the middle lobe of the right lung are the areas commonly involved If bronchial embolisms alone were the cause of bronchiectasis the right lower lobe would be affected more often than the left The obliquity of the left bronchus may be responsible for difficulty in expectorating pent up secretions in the lower part of the lung

Bronchial obstruction however explains the development of the condition in such diverse pathological states as retained foreign bodies the inhalation of infected material from the upper respiratory passages as a complication of tuberculous disease whether of the bronchial wall or of the adjacent lung lymphatic glands and in patients with carcinoma or adenoma of a bronchus

Bronchial infection as a cause of bronchiectasis

In the British literature it is possible that the rôle of lobar or segmental collapse has been exaggerated as a cause of bronchiectasis and the part played by infection under-estimated. Especially after bronchopneumonia not only the mucosa of the bronchi are infected but also wide areas of lung parenchyma If the infections are repeated the bronchi become damaged with loss of mucosa and of elastic tissue This combined with deficient expansions of damaged areas of the parenchyma which decrease aeration may well lead to dilatation of the bronchi especially when these are subjected to continued stress from repeated bouts of coughing after measles and whooping cough cylindrical and saccular bronchiectasis can then follow The process may be accentuated and accelerated by the secondary derangement of obliterative bronchitis and by the presence of enlarged lymphatic glands in the hila of the lobes secondary to the septic process in the lung and bronchial tissue The resultant areas of collapse may involve the whole lung a whole lobe or isolated segments and explain the mixed pattern of bronchiectasis so often seen especially in children whose soft-walled bronchi are more vulnerable to obstruction by enlarged glands pyogenic or tuberculous *A common example of this is noted in the frequency of middle lobe collapse* in children after respiratory infections this is due no doubt to the actual arrangement of lymph glands around the middle lobe bronchus which is specially vulnerable to glandular compression as emphasized by Brock. Although middle lobe collapse may often clear this by no means always happens and in my own series of 312 lobectomies or segmental resections in 12 per cent middle lobes were the seat of irreversible bronchiectasis and required removal Middle lobe atelectasis may persist for six months to a year before bronchiectasis develops If re-expansion has not occurred after a year the outlook is not good without operati

as persistent cough of an asthmatic type and small haemoptyses are common. Once bronchiectasis has developed it is almost invariably irreversible though partial re-aeration and decrease of the bronchial dilatation is possible (Fig 8 9)

Fibrocystic disease of the pancreas and bronchiectasis

The association of lung infections with cystic disease of the pancreas is well recognized. In these patients with gross nutritional deficiencies bronchopneumonia atelectasis bronchiectasis and emphysema are common and usually fatal. Once emphysema has developed death is usual but if the lung complications are treated early by antibiotic therapy and the

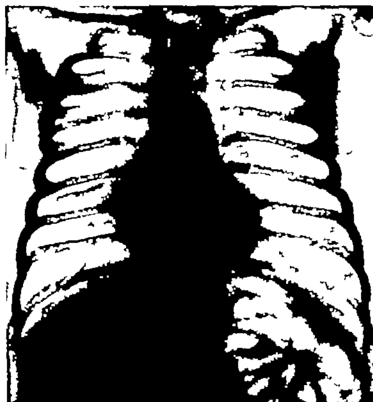


Fig 8-10 —Atelectasis (right upper lobe and middle lobe) and emphysema of the left lung with depression of the left diaphragm and widening of the intercostal spaces in a patient with fibrocystic disease of the pancreas.

nutritional condition improved occasionally recovery is possible. Andersen (1949) thinks the origin of the lung pathology may be due to a specific nutritional deficiency. The further investigations of this condition may throw light on the pathogenesis of bronchiectasis

Reversible bronchiectasis (pseudo-bronchiectasis)

After collapse of a lobe or after respiratory infections the bronchi may show a dilatation demonstrable by lipiodol bronchography. With improvement in bronchial drainage re-expansion of the collapse and a restoration to normal of the inflamed bronchial mucosa this dilatation can undoubtedly disappear (Jennings 1937). This has been proved in a considerable number of patients by follow up bronchography. The difficult point to establish is how long a lobe or segment may remain collapsed with dilated bronchi before the process becomes irreversible. I know of several children with bronchiectasis in whom the condition disappeared after a year's wait; this result was confirmed by bronchography. It is however unusual but at least six months can be spent profitably in waiting for this

agreeable sequel if the child can be treated by fresh air, breathing exercises and chemotherapy in cylindrical bronchiectasis resolution does not happen in saccular bronchiectasis

Pathology

The bronchi may dilate into cylindrical dilatation or into clearly defined saccules

The macroscopic appearances of the lobe in bronchiectasis depend largely on the degree of atelectasis present If this is extreme the lobe is solid and contains a mass of dilated bronchi, closely approximated The parenchyma is solid and often shows patches of pneumonic consolidation with extensive areas of fibrous tissue and the whole lobe is

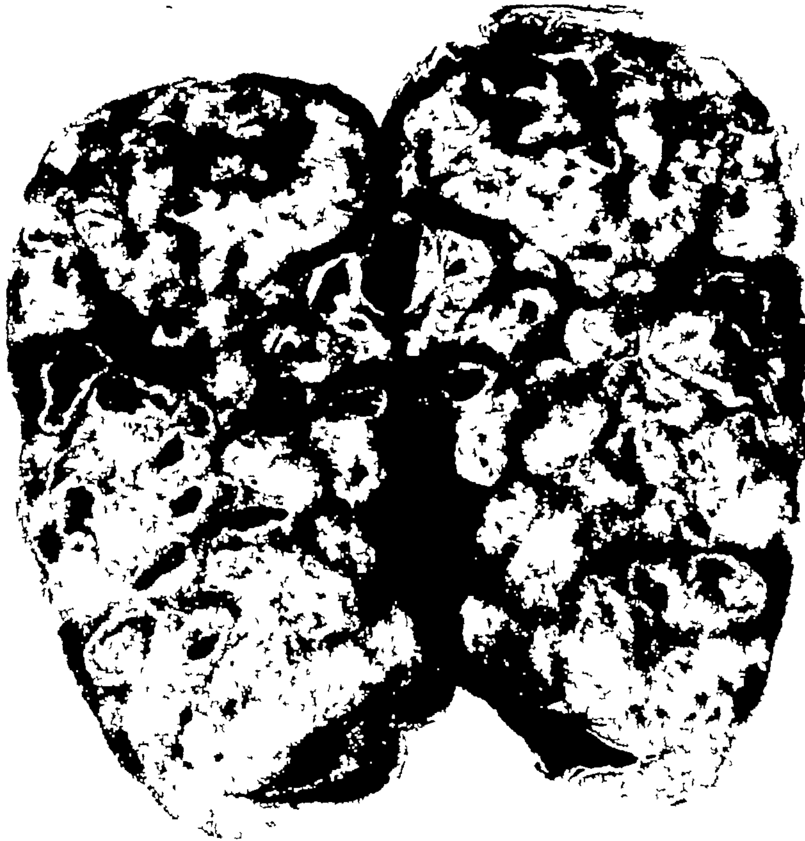


FIG 8 11 —Gross bronchiectasis of the left lung Pneumonectomy specimen (width 16 cm)

shrunken. The bronchi are dilated and may retain a reasonably good pattern or be distended into saccular spaces the mucous membrane is often swollen with ulceration in parts (Fig 8 12 (*b*)) , the elastic fibres of the bronchus are hypertrophied in areas, and fragmented in others Microscopically the ciliated bronchial mucous membrane often changes to cuboidal or flattened epithelium the spread of infection beyond the bronchial wall may produce areas of fibrosis, pneumonitis, obliteration of vessels (Fig 8 12 (*b*)),* or true suppurative foci may be present Pleural adhesions may be dense and are evidence that the disease

* The obliteration of vessels is interesting In non-tuberculous bronchiectasis the larger vessels remain intact, as demonstrated by post-lobectomy infusion with radio-opaque solutions in tuberculous disease that has destroyed the lobe or caused its collapse the reverse is the case These vascular effects probably explain why in bronchiectasis there may be a decrease in arterial oxygen saturation which is abolished after resection in fibrocaseous tuberculosis there is rarely a decrease in arterial oxygen saturation The inference is that in bronchiectasis there is a venous arterial shunt mechanism (Gobbel, Gordon, Digman and Brook, 1951)



(a)

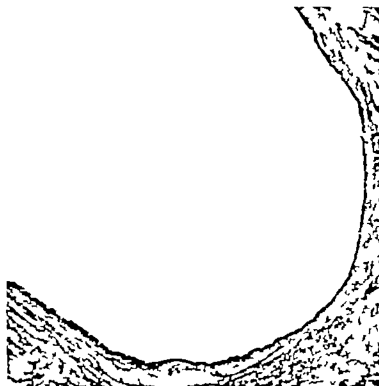


(b)

FIG 8 12

( ) Acquired bronchiectasis showing purulent exudat in the dilated bronchus and ulceration of the bronchial wall. (Dr H Baar)

(b) Acquired bronchiectasis showing infiltrative mural bronchitis disintegration of elastic fibres replacement of parenchyma by granulation tissue and obliterating endarteritis. (Dr H. Baar)



(c)

FIG 8·1*

( ) Congenit l bronchiectasis showing cystic pace lined by cubical epithelium and no inflammatory hanges of the walls of the cysts. (Dr H. Baar)

has caused pleurisy, but quite frequently severe bronchiectasis may be present without any significant adhesions

Many lobectomy specimens removed from patients with copious sputum show an apparently healthy parenchyma and at operation the lobe may have appeared quite normal Frequently there is an obvious lack of carbon pigment, evidence of a lack of full alveolar ventilation Sometimes bronchiectasis may show little or no gross radiological changes on the plain X-ray film, apart from translucency due to associated emphysema (Fig 8 13), the diagnosis being made on a bronchogram taken for the investigation of a patient with continuous expectoration of purulent sputum More usually, however, a collapsed lower lobe is seen behind the cardiac shadow or more clearly on the right side

Changes produced in the mediastinum, the lymphatic glands and the unaffected lobes of the lung

Gross alteration may develop in the position of the mediastinum, the character of the lymphatic glands and in the remaining parts of the lungs These depend largely on the degree of atelectasis and of infection Total atelectasis of one lung will lead to a marked swing over of the mediastinum to the diseased side and a considerable displacement is seen if only one lobe is completely collapsed Compensatory emphysema is often notable and its presence on one side of a chest radiograph may be the clue to the detection of a collapsed lower lobe, especially when the left lower lobe is contracted into its typical triangular shape behind the cardiac shadow

The lymphatic glands and the hilar structures may be greatly enlarged and much matted as the sequel to the infection in the bronchiectatic area These changes may provide difficulties in the surgical dissection necessary in an excisional operation

Distribution of bronchiectasis

Bronchiectasis tends to involve segments rather than lobes, the basal segments of the lower lobes being more commonly affected than those of the upper ones The lingula segments on the left and the middle lobe area on the right are, however, frequently involved, which is quite different from the incidence of tuberculosis or lung abscess which tend to attack the more posteriorly placed broncho-pulmonary segments, the apical segment of the lower lobe (dorsal lobe) is often spared from disease when bronchiectasis is involving the remaining segments of the lower lobe Acquired bronchiectasis is unusual in the upper lobes though honeycomb appearances are not uncommon, probably representing acquired disease secondary to bronchostenosis from healed tuberculous glands around the upper lobe bronchus *

Bronchiectasis is often bilateral (40 to 60 per cent) and when this is so the pattern of disease on one side is often curiously mirrored on the other For example, the combination of bronchiectasis affecting both lower lobes and the lingula on the left and the middle lobe on the right is a common one Equally striking is the picture when the disease attacks the anterior segments of both lungs (anterior bronchiectasis), if the disease is bilateral and the dilatations are present in the anterior basic segment, the middle lobe segments and the anterior segment of the right upper lobe, the corresponding areas of the left lung will usually show these anatomical changes

Bronchiectasis may affect one lobe only, the left lower lobe being the one most commonly involved (20 per cent in my own series), or it may involve segments in all lobes on one

* Overholt (1955) has rightly pointed out, however, that bronchiectasis of the anterior segment of the upper lobe may well be overlooked unless high quality bronchograms have been made and studied in his series of resections 8 per cent had involvement of the anterior segments

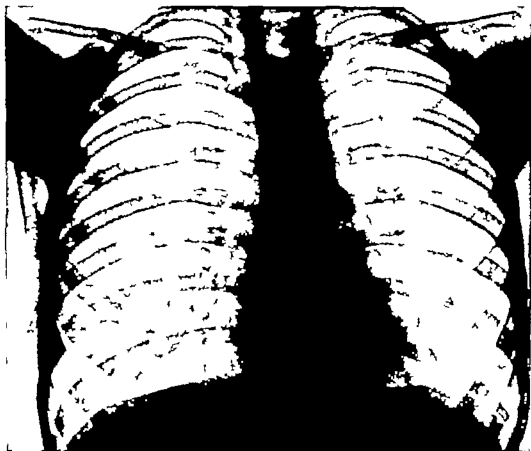


Fig 8-13 (a)—Radiograph showing translucency of left lung field in a child with cough and sputum. Because of the emphysema of the upper lobe a bronchogram was done (Fig. 8 13 (b))



Fig 8-13 (b)—Bronchogram showing extensive cylindrical bronchiectasis in left lung

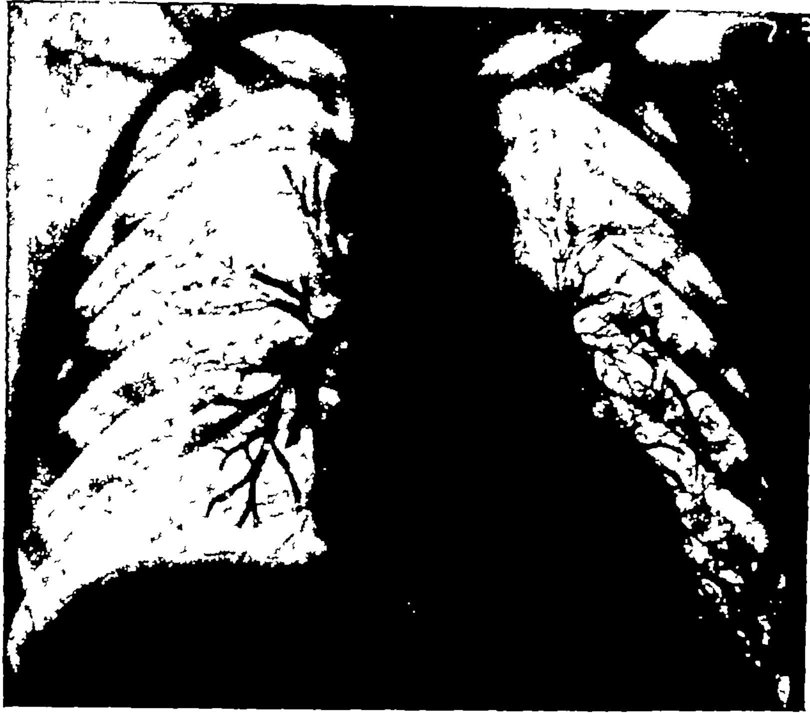


FIG 8 14 —Bronchogram showing fusiform bronchiectasis in a collapsed left lower lobe lying behind the heart

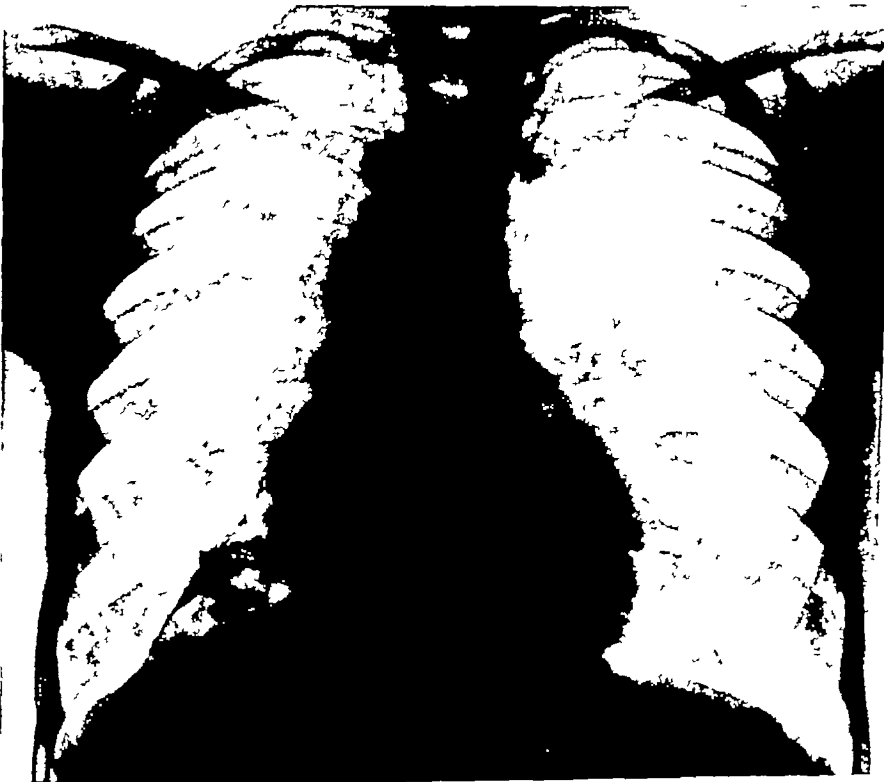


FIG 8 15 —Atelectasis right lower lobe
Mediastinal displacement to the right and increased translucency of right upper lobe due to emphysema

side with the other side quite unaffected But even in these types of distribution it is unusual to find all segments of a lobe or of a lung involved though the treatment indicated may demand total lobectomy or total pneumonectomy

When the surgical treatment of bronchiectasis was being developed in the ten years before the war many left lower lobectomies were performed for what was thought to be disease confined to that lobe only The inadequate nature of the bronchogram of that era is fully recognized the need for a bronchographic filling of every segment of both lungs became obvious when Churchill and Belsey (1939) first pointed out how frequently the lingular segment of the upper lobe was affected and every surgeon has had to remove the lingula some years after a left lower lobectomy has been executed With better bronchograms now available unilobar disease is not common and over 60 per cent of the cases of bronchiectasis seen today clearly are bilateral the commonest resection done removes the lower lobe and lingula Next in order of frequency are the left lower lobe alone and the right lower and middle lobes Middle lobe bronchiectasis alone is not infrequent being 12 per cent in my own series In the series of 312 quoted in the footnote on p 144 1 9 per cent of the resections were total pneumonectomies I believe that many of these were the end results of bronchostenosis due to compression or ulceration of the main bronchus by tuberculous glands representing a serious complication of a primary complex well described by Dillwyn Thomas as complicated primaries With the diminution of primary infection in young children this complication is becoming far less frequent It should be prevented altogether by adequate chemotherapy or by judicious operation on these glands if the radiographs show that partial bronchial obstruction is producing unilateral emphysema the precursor of atelectasis which follows total bronchial obstruction

The impressions given above were gained from a study of 312 patients under my care in whom surgery was employed Although they indicate that bilateral bronchiectasis is common they do not represent the true incidence of disease distribution as many patients with severe bilateral disease are not referred for a surgical opinion

In the whole series of 312 cases I have felt that only 18 could be accepted as being truly *congenital in origin all of these were accessory cystic lobes (dissociated lobes* or duplications) with abnormal systemic arterial supplies

Careful bronchography has indicated that in much lower lobe bronchiectasis the apical segment is free from disease it can be saved by conservative resection of the other lower lobe segments and this is particularly important when the disease is bilateral

Clinical features of bronchiectasis

Persistent cough with the production of purulent sputum are the common features but in young children the sputum is frequently swallowed and the parents story of lack of sputum must not be accepted readily nor can reliance be placed upon the amount of daily sputum as stated by most patients and after the institution of satisfactory postural drainage in hospital this amount is often twice as much as that described In most instances the greatest quantity of sputum is expelled by the patient after he wakes in the morning

Frequently the sufferer sleeps on the most affected side to prevent sputum from draining into the upper healthy tracheobronchial tree where its arrival will initiate the cough reflex

Haemoptysis is not usually severe and is commoner in adults than children although saccular disease is less common than the more usual cylindrical type of bronchiectasis haemorrhage is more frequent in that group Haemoptysis without the expectoration of purulent sputum is often reported it used to be referred to as dry bronchiectasis

but when these patients are in hospital the adoption of active postural drainage movements invariably discloses the presence of true sputum

One of the notable changes in this disease is the disappearance of the patients who used to present themselves as social outcasts, because of their offensive sputum , the first five patients on whom I operated in 1935 all had this offensive sputum but it is now rare, partly because the patients with chronic cough are investigated before advanced changes have taken place in the affected lung or lungs, but chiefly from a change in the bacterial flora (see p 129) Similarly it is unusual to see patients with advanced toxaemia and amyloid disease, though less degrees of chronic ill-health are common Most of the children seen are much below their weight and height and normal development often follows successful lobectomy , fatigue and frequent pyrexial illnesses after colds are common features the important history of repeated " pneumonia " often indicates recurrent infections in atelectatic lobes giving rise to pyrexia, dyspnoea, increase in cough and physical signs over the affected area Cerebral abscess is a rare complication

Clubbing of the fingers is common but may be absent even in severe degrees of infected bronchiectasis

The physical signs in the chest may be surprisingly minimal, sometimes absent , when signs are present most reliance will be placed on poor chest wall movement over the affected area, slight dullness on percussion and the presence of moist râles If the affected lobe is atelectatic bronchial breath sounds may be audible, but even when the radiograph shows undeniable evidence of a triangular collapsed lower lobe the stethoscope may fail to detect bronchial breathing if the bronchus at that moment is blocked by intrabronchial contents or because of complete occlusion, the result of extrabronchial compression from enlarged lymph glands

The diagnosis will be made in most patients if the history of a persistent cough, often with associated finger clubbing, leads to a complete radiological examination

Radiological appearances

The whole plan of treatment will depend upon the radiological findings Before the patient is submitted to surgery a full account must be available of the state of every bronchopulmonary segment of both lungs and this can only be obtained after lipiodol bronchography

The preliminary plain radiograph The appearances vary from negligible changes of increased shadows beyond the normal ones cast by the pulmonary vessels to the gross appearances of total lung or lobe atelectasis associated with considerable displacement of the trachea, mediastinum and heart to the side of the airless lung and with compensatory emphysema of the other lung or of the lobe not affected by atelectasis Atelectasis is most often shown as a triangular dense shadow and this will be accompanied by translucency of the emphysematous left upper lobe (see Figs 8 13 (*a*) and (*b*)) In saccular bronchiectasis or in cystic disease of the lung the " cysts " may be shown quite clearly (Fig 8 16)

Bronchography

The performance of this is in every respect as important as the resection operation, prognosis and treatment depending upon accurate bronchograms fully studied and noted To attain really good bronchograms the patient should have undergone a preliminary course of postural drainage , the presence of thick sputum not only interferes with the adherence of thick viscous iodized oil to the walls of the bronchi, but is often the cause of severe coughing during the operation which will ruin the bronchographic appearances

Methods There are several ways of producing a satisfactory filling of the bronchi.

Except in children one side should be filled so that accurate lateral views can be obtained without the confusion of overlapping shadows being cast by the presence of oil in the other lung But good bronchograms can be obtained by bilateral filling if oblique films are taken

The oil may be introduced by

(1) an intranasal catheter or a thin tube passed through an intratracheal tube
(2) dropping lipiodol over the back of the tongue into a cocained larynx
(3) a puncture through the crico thyroid membrane



FIG 8 16—Gross saccular bronchiectasis in a woman of 45 years.

In all methods success will depend upon securing the co-operation of the patient and the radiological staff the pictures must be made in the X ray room to avoid all delays (during which even the best patient may cough) and to prevent the iodized oil passing too far into the alveoli and so producing a blurred indeterminate picture The viscous oil should not be warmed because this makes it too liquid which encourages alveolar filling instead of delineation of the bronchial wall Adherence of the oil and avoidance of alveolar filling is increased by adding 4 to 5 grammes of sulphanilamide powder to each ampoule of lipiodol The crico-thyroid puncture method is not recommended it is uncomfortable and has possible risks not associated with the other methods

Bronchography in children I am indebted to Dr Roy Astley for this account of his method

The child is admitted to the ward one or two days beforehand for postural drainage and breathing exercises if there is much sputum this preparation is continued for several additional days On the day of the examination the child is given rectal bromethol 0·075 ml per kilo body weight and atropine gr 1/100 (0 6 mgm) twenty minutes before leaving the ward

(a) (b)

FIG 8 17—Bronchogram in an adult, both sides filled at the same time

The study of the postero anterior and oblique radiographs indicates "cystic bronchiectasis" of right lower lobe, a bronchiectatic accessory right tracheal lobe and a normal left lung in all segments



FIG 8 18—Saccular or cystic bronchiectasis involving all lobes of the right lung in a child of 4 years with copious sputum

The oblique view of the left lung shows that side to be free from disease Uneventful pneumonectomy

In the X ray department anaesthesia is induced with cyclopropane and oxygen When the jaw is relaxed the larynx and trachea are sprayed with local anaesthetic and the largest possible oral endotracheal tube is introduced under direct vision so that the tip lies just above the carina As soon as the tube is in place the tracheo bronchial tree is thoroughly sucked out turning the child on to each side in turn and pummelling the chest wall Anaesthesia is maintained with nitrous oxide oxygen and minimal trilene The patient is then raised to a sitting position and the radiologist introduces iodized oil into the trachea through a narrow plastic tube inserted inside the endotracheal tube With the child lean ing towards the side under examination and slightly backwards one to two and a half ml of iodized oil (according to the size of the subject) are injected and the child is gently rocked backwards and forwards three or four times After a pause of about thirty seconds the sitting child is bent forwards with the shoulder of the side under examination towards the ipsilateral knee and another half to one and a half ml of iodized oil are injected Again a pause of thirty seconds follows during which this folded up position is maintained Then the child is bent sideways over the edge of the couch so that the head is level with its edge and a similar amount of oil is injected On completion of the injection the child is momentarily raised to the vertical position before resuming the sideways posture for another half minute Between injections endotracheal anaesthesia is continued During the final stages of posturing an intravenous injection of an ultra-short acting muscle relaxant drug is given The child is then carried (with the side containing the iodized oil underneath and the head lower than the feet to complete upper lobe filling) to the X ray table where supine oblique and antero posterior teleradiographs are taken in quick succession aided by the respiratory paralysis that the relaxant drug has produced Apparatus for giving oxygen is ready beside the X ray set with its aid in addition to the pictures with the chest relaxed an extra picture is taken with the lungs inflated (abnormalities may be evident in one phase of respiration that are not seen in the other)

On completion of the radiology as much iodized oil as possible is removed by suction Natural respiration soon returns and light anaesthesia is continued while the technique is repeated once more to examine the opposite side Meanwhile the radiographs are processed so that they may be inspected and if necessary any incompletely demonstrated segments shown by a third filling Finally the tracheo bronchial tree is sucked clear and the child returned to the ward

Important points are the preliminary postural drainage and the bronchial suction during the induction of the anaesthetic to ensure that the iodized oil can penetrate into and demonstrate the entire bronchial tree It is a common failing to use too much contrast medium the amount should be small so that the bronchi are coated rather than completely filled With the volumes suggested above very little residue remains after the broncho graphy and it is therefore unnecessary to use the more irritant water-soluble contrast media It is very exceptional to need fluoroscopy to control the examination This technique also has the advantage that both lungs are examined at the one session and that the child has no unpleasant memories to hinder subsequent treatment or follow up bronchography

The treatment of bronchiectasis

The problem under discussion relates to bronchiectasis produced other than by bronchial neoplasms pulmonary tuberculosis lung abscess or foreign body though frequently treat ment in that group calls for lung lobe or segment resection

Although life is undoubtedly shortened by severe bronchiectasis the arrival of anti biotics and sulpha drugs has greatly decreased the mortality rate in patients up to middle

age The seriousness of the disease lies in its morbidity , discomfort, mental distress, loss of school and working hours, social and economic distress and necessary confinement to bed during attacks of fever and " pneumonia " are all too obvious in many of the patients The symptoms are worse from the ages of 5 to 12 and from 25 onwards , a notable improvement is often seen in the 'teens The melancholy after-history of patients with bronchiectasis should be borne in mind when the treatment of the disease in children is being considered, and the clinical condition of many patients in the late twenties and thirties who produce daily large quantities of sputum and exhibit the breathlessness and cyanosis of advanced pulmonary heart disease is a pathetic one

In the usual forms of bronchiectasis, apart from the chronic ill-health so often present, the dangers to life from metastatic brain abscess, lung abscess, foetid empyema, toxaemia and right-sided heart failure are less today than in the pre-antibiotic era

The distressing constant expectoration of sputum, sometimes offensive, the recurrent haemoptysis, the repeated " pneumonia " and the gradual decrease in respiratory efficiency indicate the need for adequate treatment , when adequate bronchography indicates that complete removal of the bronchiectatic areas is possible and will not cause respiratory crippling, resection is the most effective measure Operation is not advisable in the elderly, the eldest in my series being 61 , it is contra-indicated if the resections involved would lead to the sacrifice of so much lung tissue that a reasonable respiratory function would be unlikely , it can be said, however, that some patients who have undergone resection of both lower lobes and of the lingular and middle lobes are free from dyspnoea and have good respiratory function Bilateral disease is certainly not a contra-indication to successful surgery since the establishment of safe techniques for segmental resection but may be followed by poor results

Although established bronchiectasis rarely spreads to other lobes, as is commonly believed,* the previously healthy lung tissue is subjected to repeated attacks of infection and is grossly damaged by an increase in compensatory emphysema which passes on to the pathological state and is the cause, sometimes, of right-sided heart failure The constant coughing from an infected collapsed lobe often increases the extent of emphysema in the already over-distended associated lobes which may be further affected by the development of obliterative bronchitis, the result of frequent re-infection

It is not the mortality rate that has induced a tendency everywhere to be far more cautious in advising resections for bronchiectasis unless surgery can eradicate all areas of disease the results are disappointing as sputum may still be expectorated , in an attempt to do this, extensive bilateral surgery became popular, especially in children In some children, the eradication of disease by these extensive multi-lobar or multi-segmental resections has undoubtedly led to the sacrifice of a good deal of functioning lung tissue and this has been seen in our follow-up studies to have led to dyspnoea on exertion and a notable failure in some of the patients to grow or put on weight These poor results have been seen especially in children with bronchitis in addition to their bronchiectasis, in those with severe upper paranasal sinus infection and in those with emphysema or asthma In many of these children the bronchiectasis is not associated with atelectasis The best results, and these are excellent, have followed surgery in which collapsed, bronchiectatic and functionless lobes or segments have been removed Even in extensive bilateral disease the palliative effect of removing one or more collapsed, pus-producing lobes has been good

* Dr R Astley at the Children's Hospital, Birmingham, has repeated many bronchograms in patients with inoperable bronchiectasis and rarely has found bronchiectasis developing in another lobe, though progression of the bronchiectasis in the affected lobes has been noted in many

It is clear that a very critical survey of the patient must be made before surgery is advised In children especially there is a remarkable tendency for the symptoms to diminish once the age of 10 has been reached due perhaps to the fact that the bronchial passages are larger and that the ages of 10 to 20 represent a healthy period of life when infections are neither so common nor serious

In advising resection the surgeon must add up the post-operative risks of morbidity admittedly uncommon today but still including post-operative atelectasis fistula and empyema In following up a large series probably most observers find that cough persists in about 40 per cent of the patients even when the bronchogram shows no bronchiectasis It is due to a bronchitis that persists

Amyloid disease (rare unless associated with tuberculosis) is no longer a contra indication to resection and in fact its early diagnosis in a patient with bronchiectasis is an indication for resection if the case is operable for it is not irreversible in its early stages

Palliative treatment Some patients because of the extensive involvement of both lungs beyond the limits of possible segmental resection are quite unfit for excision They can be improved by active postural drainage breathing exercises and by antibiotic and sulpha therapy A period in hospital under the active supervision of the physiotherapist who will teach and insist on the correct methods of postural drainage and of breathing is probably the most important part of a palliative regime The simple suggestion to the patient that he should lean over the edge of the bed is useless Children often obtain great help from a change in climatic environment if they live in industrial cities

The dangers of surgical treatment This must be reviewed in terms of mortality rate and the cure or relief of symptoms and both depend on the types subjected to operation Bilateral disease and the general condition of the patient have a far greater effect than age Before the 1939–45 war many surgeons were reluctant to operate on patients over 40 but this view is no longer held in fact a patient of 50 with unilateral disease may well be a better operative risk than a child of 6 with bilateral disease though children stand major thoracic operations with surprisingly little upset In the very young children however the post-operative treatment is difficult if the patient cannot co-operate by the intelligent use of coughing and young subjects show a higher rate of atelectasis in the remaining lobes than the older ones In a recent series of 312 resections for bronchiectasis there was one death in the patients under 14 (191 operated on in this age group) and 2 in patients over that age (121 in this age group were operated upon) there were however many more examples of post-operative atelectasis in the younger age group The ideal time for lobectomy in children is when they are old enough to co-operate in their physiotherapeutic management and young enough to forget rapidly the horrors of surgery perhaps the ages of 8 to 12 are ideal

Results These have improved with progress in anaesthesia pre- and post-operative treatment (especially with reference to the evacuation of the tracheo-bronchial secretions by postural drainage ward discipline and methods of suction by intranasal catheter or by bronchoscopy) and in the actual technique of the resection which is greatly assisted by modern antibiotic and chemotherapeutic measures

Post-operative morbidity If all the diseased tissue is completely resected and the remaining lung tissue is healthy and adequate in area for full lung function a cure will be obtained and this should be achieved in 80 per cent of patients Another 10–15 per cent should be greatly improved the chief disability complained of in this group and in those of real failure being persistent thoracic pain and persistence of some sputum

(*a*) *Thoracic pain* This may be widespread over the operated side but more commonly is complained of along the line of the thoracotomy incision and extending obliquely downwards beyond the anterior limit of the healed wound, and is due to operative trauma to the intercostal nerve Para-vertebral injection of procaine in oil or resection of the intercostal nerve often fails to give relief

(*b*) *Persistence of sputum* This is due to four principal causes

(1) All the diseased segments have not been removed This is becoming increasingly less frequent as the result of better bronchography and a more accurate pre-operative evaluation of the bronchograms. In the early days of resection surgery it was not unusual for an involved lingula or middle lobe to be overlooked largely because the iodized oil filling of the bronchi was inadequate or because good lateral or oblique views of the filled lung were not obtained

(2) Faulty re-expansion of the lung tissue Post-operatively the remaining lobes after re-expanding fully in the first twenty-four hours may collapse later as the result of pent-up bronchial secretions, the result of inadequate cough This is far commoner in patients with bilateral disease, for there is still a large reservoir of sputum after one side only has been operated upon The insistence on adequate post-operative cough aided by frequent change of position and with the constant help of the nursing and physiotherapeutic staff usually overcomes this retention of sputum If this is inadequate, intratracheal suction or bronchoscopic aspiration is essential and its need can only be indicated by the frequent taking of post-operative radiographs In a few patients all efforts to obtain full and early re-expansion fail and these collapsed segments may lead to the continuous production of sputum and ultimately become bronchiectatic and require (if possible) further surgical resection Seven of the resections in 312 operations for bronchiectasis were carried out for the removal of permanently collapsed lobes after previous lobectomy (residual lobectomy) (see Fig 8 3)

(3) The result of empyema formation With the substitution of dissection lobectomy (Blades and Kent, 1940) for the old tourniquet method of resection and with the improvements produced by the use of antibiotic therapy this complication has become rare perhaps the most usual type is the formation of a small empyema around the bronchus stump ("stump abscess") When this develops the bronchus usually opens and pus is coughed up which is usually blood-stained If the remainder of the lung has fully re-expanded this may not be a serious complication and the use of postural drainage, bronchoscopic aspiration and chemotherapy usually obviate the need for formal drainage, though this must not be delayed if the symptoms persist

The usual cause of post-operative empyema is undoubtedly the development of a bronchial fistula With the adoption of the technique of closure of "the open" bronchus which obviates the inclusion of any crushed tissue in the line of suture and the use of pre- and post-operative chemotherapy, this complication has become rare Of the 312 operations already mentioned, one pneumonectomy patient out of 36 who survived total lung excision developed a fistula and empyema , 8 patients out of the lobectomies or segmental resections developed an empyema , these were drained, but 3 developed serious disease in the remaining lobe which required residual lobectomy The complication, when it develops, is therefore a serious one

In children especially, the risk of empyema development is small , in the operations of lobectomy or segmental resection on 191 patients under the age of 14, there were 4 patients who developed empyema, both the result of fistula The bronchial wall in children is easy to handle, accepts sutures well and heals rapidly

(4) *Purulent bronchitis* Many patients with real bronchiectasis have a generalized associated bronchitis usually catarrhal but sometimes purulent There can be no guarantee that this condition will disappear completely after excision of the bronchiectatic area the combination is most usual in patients with the fusiform type of bronchiectasis If a conservative attitude is favoured in the treatment of bronchiectasis this type of disease deserves special consideration its assessment is not easy but usually the symptoms of constant coughing in a child who has generalized moist râles over both lungs calls for caution Residence in mild climates away from the smoke and dust of large industrial cities may lead to great improvement and is of especial value in the months before lobectomy is undertaken

The pre-operative treatment The patient is admitted at least a week before operation for pre-operative measures such as postural drainage and breathing exercises improvement of the general condition by bed rest a balanced diet the administration of iron and the use of blood transfusion if there is significant anaemia The patient can gain confidence in those who are to supervise the post-operative period and should be trained in the use of the face and nose oxygen mask and the oxygen tent From the first the necessity for pre-operative cough and postural drainage is emphasized and the need and reasons for continuing this after operation explained If possible the patient should be placed between two satisfied convalescent patients Penicillin inhalation therapy is used in this waiting period and parenteral penicillin or aureomycin given for twenty four hours before operation It is probably unwise to carry out lobectomy soon after lipiodol bronchography until the radiographs show that the main oil content has been expectorated.

Care of associated infection of the paranasal sinuses and of dental sepsis Many of these patients have infected nasal sinuses the opinion of an ear nose and throat surgeon should be sought Illogical as it may appear radical surgical treatment of these sinuses should be postponed until after resection of the affected lung tissue for extensive nasal operations are badly borne by patients with bronchiectasis and carry a risk of accentuating lung infection Sometimes the sinus condition may clear rapidly after the lobectomy but lesser measures such as antrum puncture wash-outs and the use of penicillin inhalation may be of value Gross dental sepsis should be treated before lung resection operations

The extent of resection in the treatment of bronchiectasis

If all the diseased tissue is removed the results are excellent in the absence of post-operative complications such as delayed re-expansion of the remaining lung tissue or persistent atelectasis The distribution of bronchiectasis has probably reached its final form by the time the disease has been diagnosed accurately by bronchography and the condition rarely spreads to other lobes though increasing progressively in the affected areas Serious complications such as lung abscess empyema or cerebral abscess may supervene at any stage but this is unusual If the resections necessary to remove all diseased segments are too extensive the patient may be left as a permanent respiratory cripple and in children extensive resection may inhibit growth and development For this reason the modern aim is to resect only those segments that are actually diseased and every effort is made to conserve healthy segments Frequently in bilateral bronchiectasis segments may be involved in all lobes though usually the lower lobes the middle lobe and the lingula are the areas implicated Often the apical segment of the lower lobe on each side may be the sole areas of those lobes free from disease and the bronchogram may show that they have undergone considerable hypertrophy being larger in size than the remainder of the lobe Such segments may well be spared the basic segments only being resected

1. Lobectomy. Unless there are completely healthy segments present the whole lobe should be sacrified sometimes in operations for bilateral bronchiectasis both lower lobes together with the middle lobe on the right and the lingular segment on the left must be removed In spite of such extensive resections the physiological and anatomical result may be extremely satisfactory, the main difficulty in such operative programmes being the danger of post-operative respiratory insufficiency Atelectasis in the post-operative phase of the first resection is a risk, because of the persistence of sputum from the unoperated side

If the disease is confined to the left lower lobe the whole lobe should be excised even if the bronchogram shows a healthy apical segment as there is always a risk that this segment, if left, may collapse and become bronchiectatic, its loss would not impair respiratory function It can, however, be conserved in bilateral lower lobectomies especially if the lingula and middle lobes (as is often the case) have to be resected Leigh Collis (1953) has published a large series of patients in which this was done with very good results

It is often of value to remove a single lobe as a palliative method in bronchiectasis affecting other parts of the lungs if it is atelectatic or the site of gross saccular bronchiectasis In many patients originally selected for bilateral surgery the resection of the left lower lobe alone has so relieved symptoms that further procedures on the other side have not been necessary The ideal patient for lobectomy has strictly unilobar disease but this is not common and cannot be expected in more than 30 per cent of patients The use of lobectomy for bilateral disease has greatly extended the scope of these operations

Although a considerable number of patients with upper lobe bronchiectasis are seen, the symptoms are usually insufficient to justify resection and the prognosis of bronchiectasis in these lobes seems to be good without surgical excision, persistent haemoptysis, however, is an indication for their resection

Persistent collapse and bronchiectasis of the middle lobe may be quite symptomless in some patients, however, symptoms may be important In children this condition may be the sole cause of a persistent cough with general ill-health If the remainder of the lungs are free from bronchiectasis or bronchitis and at least a year has been allowed to elapse before surgery is contemplated, the results of middle lobectomy probably provide the best results of all excisional surgery for bronchiectasis In adults this condition may be the cause of considerable haemoptysis which is not infrequently due to the ulceration of long-standing calcification of old healed tuberculous glands This is the commonest cause of the condition known as broncholithiasis

2. Pneumonectomy. This operation is reserved for patients with a sound contralateral lung, the diseased side showing bronchiectasis so extensive that lobectomy or segmental resections would be useless It is best tolerated by young patients who have powers of rapid physiological adjustment and can be safely executed at any age under 14, even in the first years of life It is a dangerous procedure in middle-aged patients who have already developed severe emphysema in the "good" lung with a consequent hypertension in the pulmonary arterial tree, but may be justified because it removes a large pus-secreting area which further impairs the crippled respiratory system

3 Segmental resections The employment of segmental resections is of particular value in bilateral bronchiectasis where the aim is to conserve all the normal lung tissue, and by this method patients are successfully treated even with segments involved in all lobes of the lung Frequently in lower lobe bronchiectasis the apical segment escapes bronchiectatic changes and can be spared Not infrequently bronchiectasis attacks the anterior segments of the upper and lower lobes and also the middle lobe or the lingula (anterior bronchiectasis) It is usually better to treat this condition conservatively if it

is bilateral but in patients with disease confined to one side with considerable symptoms in whom surgery is considered justifiable segmental resections should be employed





Fig 8 19 Fig 8 20

Fig 8 19 —Bronchogram of right lung showing bronchiectasis of the right middle lobe and the anterior and posterior segments of the upper lobe

Because in this child bronchiectasis existed in three segments of the left lung also, the extent of resection indicated on the right side was middle lobectomy and segmental resection of the anterior and posterior segments of the upper lobe as the aim clearly is to conserve as much healthy lung tissue as possible as bilateral resections were required.

Fig 8·20 —Left oblique view of bronchogram of right and left lung

Severe bronchiectasis of the middle basic segment (lateral basic segment) of the right side the cause of constant bouts of pyrexia and sputum production. An ideal indication for segmental resection which relieved all the symptoms.

Excision operations

In addition to the operative details given below references to the anatomy of the bronchi and vessels of the lungs are given in Chapter 1 the operation of pneumonectomy has been detailed in Chapter 12

1 Lobectomy

The pre-operative care the position on the operating table and the anaesthetic requirements have been considered in Chapters 3 and 4 Different procedures are indicated for different lobes The lower lobes the right middle lobe and the lingula segments are exposed by a wide posterolateral thoracotomy through the sixth intercostal space the increasing tendency to use the sixth interspace instead of the seventh is based on the easier approach to the hilar vessels which counterbalances the difficulties encountered if there are strong basal adhesions to the diaphragm especially in the posterolateral depths of the phrenicocostal sinus Access to the upper lobes is through the fifth interspace The exposure should be wide employing the full extent of the space with resection of a segment of rib posteriorly in big patients

Lower lobectomy Any adhesions to the lobe in the region of the fissure and to the chest wall are freely divided if there is no free pleural space the divided edge of the periosteum and parietal pleura is held upwards and outwards by a series of small artery forceps The lung is then held down gently while the adhesions are divided largely by scissor dissection As soon as sufficient space has been developed the chest is opened by means of a rib spreader in children this is done effectively by the classical Tuffier retractor

but in bigger patients the Finochietto spreader or Price Thomas retractor (see p 78) is necessary As soon as the ribs have been spread adequately, further adhesion severance is greatly eased and is accomplished by dividing, with lobectomy scissors, adhesions illuminated by a malleable chest light of the Nelson pattern placed deep to the fibrous bands, this trans-illumination at once discloses the presence of large vessels or lung tissue in the adhesions The major portions of the exposed lung are then covered with saline pads

The posterior end of the great oblique fissure is defined clearly this may involve division of interlobar adhesions or the section of bridges of lung tissue that frequently unite the upper and lower lobes at this site When the fissure has been defined freely the apex of the lower lobe is displaced forwards and possibly held in that position by a small Duval lung forceps

The lower lobe bronchus lying above the inferior pulmonary vein is then seen through the parietal pleura which is freely divided by scissor dissection It is an advantage to secure this bronchus as early as possible to avoid any risk of forcing muco-pus into the rest of the bronchial tree during manipulation of the lobe itself After the bronchus has been cleared of its sheath (this requires division and ligation of the bronchial arteries) a temporary clamp is placed across it well below its origin from the main bronchus Later a higher section can be done just before the occluding bronchial sutures are placed

If, however, the bronchus is a difficult one to expose and clear because of the presence of enlarged lymphatic glands or the presence of dense peri-bronchial inflammatory fibrous tissue, the attempt should be abandoned and attention directed to securing the pulmonary arteries These are exposed by dividing the peri-vascular sheath covering the vessel, as it lies in the depths of the fissure nearer to its posterior than anterior end The free division of this sheath, often a difficult procedure in the presence of matted lymphatic glands, is essential and the vessel should not be encircled by curved artery forceps until the true wall of the vessel has been exposed Once the sheath has been opened the anatomical arrangements of the vessels can be established The first vessel to be seen is usually the short stumpy branch passing to the apical segment of the lower lobe, on the right side opposite to this is the middle lobe branch (usually covered by a lymphatic gland) The artery to the lingula will be in a corresponding site on the left side, the vessel below these tributaries then passes on into the main lobe where it may quickly divide into the segmental arteries No vessels should be tied until the anatomy has been fully displayed, for the arrangements of the vessels may not follow the set pattern described above The chief danger arises when the main pulmonary artery curves down into the great fissure, giving off branches from its convexity to the apical segment, lingula and lower lobe close to each other The actual securing, ligation and division of the vessels varies in each case it is frequently convenient to deal first with the apical artery and then the main lobar artery so that two sets of ligatures are needed instead of one A simple convenient technique is to pass a curved forceps of the Moynihan cholecystectomy type beneath the thoroughly cleared vessels and to grasp in its open tip a thread or silk ligature held down to it by a pair of long artery forceps, the cholecystectomy clamp is then closed and the ligature brought round the vessel and tied (see Fig 12 16 (*a*)) Before division of the vessel between two ligatures a fine thread or silk suture may be placed through the proximal end of the vessel below the first ligature as an added precaution

If the lingula or middle lobe is to be removed at the same operation the vessel supplying those segments should be clearly delineated, secured and tied at this stage as the fissure is well exposed and its limits retracted If the patient is in the lateral thoracotomy position the middle lobe bronchus and the lingular bronchus will be on a plane deeper to the artery

and may be secured clamped and divided before the lower lobe is retracted forwards towards the mediastinum for the next stage of the lobectomy which involves the isolation and division of the main lower lobe bronchus and then of the large inferior pulmonary vein

The bronchus If this has not been secured before the pulmonary artery has been ligated and divided steps for its isolation and division are now taken and this necessitates a thorough clearing of all peri bronchial tissue by a mixture of scissor and swab dissection this dissection must be such that the origin of the structure from the main stem bronchus is seen clearly If this is omitted the main stem bronchus may be endangered and the clamp must not be placed on the lower lobe bronchus until this has been isolated The lower bronchus is then divided above one clamp the proximal open end being closed by interrupted sutures step by step as it is cut across (see Fig 12 16)

The bronchus is resected close to the parent stem to avoid leaving a stump with a poor blood supply and a small sump that might be a persistent source of infected bronchial secretions This end is best achieved by the use of a suture of the open bronchus technique described on page 273 Alternatively if the bronchus is divided between two clamps the one on the stump is removed and all crushed tissue together with any length of bronchus between it and the main bronchus is excised This will leave an opening into the main bronchus at the site of the origin of the bronchus which is closed by interrupted fine thread or silk sutures The simplest type of closure is the best and is achieved by through and through sutures tied sufficiently firmly to provide certain occlusion but not so tightly that necrosis of the bronchial wall will follow These sutures are left long and are subsequently re-threaded with needles so that a freely mobilized but pedicled pleural flap can be stitched over the sutured bronchial opening The lobe is then lifted forwards and upwards by traction on the bronchus clamp to facilitate the exposure of the inferior pulmonary vein.

The inferior pulmonary vein After the division of the bronchus this vessel is seen just below it The overlying parietal pleura is divided freely the areolar tissue cleared and the vessel is encircled by curved forceps which pick up ligatures passed down to it as in the case of the pulmonary artery Extra length of vessel may be obtained by ligating separately the two main branches of the vessel as they emerge from the lobe After the inferior pulmonary vein has been divided the lobe is still attached by the ligamentum latum pulmonis which leads down from the inferior border of the vein to the mediastinal tissues this is divided between clamps as vessels are invariably present in it Any remaining adhesions between the lobe and the parietes and diaphragm are divided and the resected portion of the lung is removed.

If the lower lobe is adherent to a middle lobe or a lingula that is diseased in the front part of the fissure these two segments are removed in one piece with the lower lobe after they have been isolated.

The chest is closed in layers and the remaining lobe fully re-inflated by the anaesthetist A drainage tube which will be connected to a water sealed bottle is left in the pleural cavity and emerges through a small stab wound through the skin and an intercostal space below the main wound

Middle lobectomy The removal of the middle lobe for bronchiectasis is a relatively common operation When associated with a non tuberculous etiology it is *usually* a simple operation but the same cannot be said of resection for lobes collapsed as the result of tuberculous lymphadenitis or endobronchial tuberculosis In the *latter* instance the peri vascular sheath of the artery supplying the middle lobe may be obliterated by cirrhotic tissue and the presence of calcified nodes which render isolation of the vessel *difficult*

The exposure is usually through the sixth right intercostal space the fissure between the lower and middle lobe is carefully exposed and the sheath of the main pulmonary artery fully opened Usually the artery to the middle lobe leaves the main artery opposite, but at a slightly higher level than the branch to the apical segment of the lower lobe, sometimes two branches are found After this vessel has been secured and divided, the middle lobe bronchus will be seen this is isolated and divided between small curved clamps If gentle pressure is executed on the clamp on the distal bronchial end, the middle lobe will start to peel away from its attachment to the upper and lower lobe, pathological adhesions being divided during this process When the peeling process has proceeded for a few centimetres the middle lobe vein is seen on a plane anterior to the bronchus and is secured, divided and tied Frequently this vein enters the pericardium as a separate trunk and an alternative method of securing it is to seek it on the mediastinal aspect of the middle lobe as that lies on the pericardium

The bronchus is dealt with in the way already described in lower lobectomy

Lingulectomy. If the lingula is to be resected alone the procedure adopted is very similar to that for middle lobectomy, but the artery lies at a somewhat higher level than that to the middle lobe for that reason a good exposure of the main pulmonary artery in the great fissure is essential once the lingular artery has been divided the bronchus is seen lying deep to it if the operation is conducted through the normal postero-lateral approach this bronchus must be fully exposed before it is clamped as damage to the upper lobe bronchus is possible if its anatomical disposition is not fully displayed Once the bronchus has been divided the lingular vein will be brought into view when a little " peeling " has taken place this vein drains into the superior pulmonary vein

Upper lobectomy. Although this operation is far more frequently used in tuberculosis than in simple bronchiectasis it is convenient to describe it here It is a more difficult operation than lower lobectomy because of the more complex arrangement of the arteries leaving the main pulmonary trunk

The chest is opened widely through the fifth interspace On the right side the apex of the lobe is depressed downwards after all adhesions have been freed in resection for tuberculous disease this mobilization often involves an extra-pleural dissection to avoid the risk of opening into tuberculous tissue Below the azygos vein the pleura is freely divided to expose the apical artery, this is isolated, divided and tied Deep to it the upper lobe bronchus is exposed, cleaned and clamped Once this bronchus has been divided, access to the superior pulmonary vein branches is eased this vein is then cleared carefully of its adventitious covering, this is essential as the main pulmonary artery is an immediate posterior relation to it When the vein has been secured and divided, the sheath of the main pulmonary artery as it descends to the lower and middle lobes is thoroughly opened; the smaller vessels supplying the anterior and posterior segments of the upper lobe can then be fully displayed and secured The dissection of the main pulmonary artery should be adequate enough to expose fully the middle lobe artery and that to the apical segment of the lower lobe these vessels should be constantly in view as the lobe is dissected free from any normal or pathological adhesion to the lower and middle lobes The chief danger in upper lobectomy is always to the main pulmonary artery which may be torn as the lobe to be removed is pulled upon if all small vessels supplying it have not been divided and tied

Left upper lobectomy is more difficult than on the right side because of the many small vessels that may leave the main pulmonary trunk, after it has swept round the upper lobe bronchus If as a first step the left main pulmonary artery is cleared and encircled by a

thick linen tape light temporary retraction of the vessel can be maintained while its branches to the upper lobe are secured the apical branch is dealt with as on the right side Before the upper lobe bronchus is clamped off the superior pulmonary vein and the branches of the artery beyond the bronchus are secured and divided these arteries vary greatly in number and can be found safely if the sheath of the main artery is thoroughly cleared

The bronchus is then clamped and divided The lobe is held over to the mediastinum and the arteries to the posterior segment and to the lingula are secured The lobe is then removed and the bronchus sutured in the normal way

2 Pneumonectomy

Although occasionally a patient may present bronchiectasis in all lobes of one lung of such a distribution that multi-segmental resections may be employed with success wide-spread disease throughout the lung with a sound contralateral lung is usually an indication for pneumonectomy This operation may be available to patients of all ages but the best physiological results are seen when the operation has been done on young children and the procedure is safe in the earliest years The operation is along the lines of extrapericardial dissection pneumonectomy for carcinoma as described on page 271

3 Broncho-pulmonary segmental resections (see also p 10)

Surgical techniques have been standardized for the removal of any broncho pulmonary segments without damage to the adjacent healthy areas of lung tissue (Pilcher 1944 Overholt 1950) and great progress has been made since the original publication of Churchill and Belsey (1939) describing lingulectomy Segmental resection is especially indicated in bilateral bronchiectasis The commonest segmental resection practised is undoubtedly on the lingula process of the left upper lobe but the recent practice of conserving the apical segment of the lower lobe when the remainder of the lower lobe is diseased has gained wide popularity

Technical principles underlying segmental resection Each broncho-pulmonary segment has its own individual artery and bronchus its venous drainage may be partly to the neighbouring segment There is an avascular line of cleavage between each segment but the visceral pleura is a continuous sheet covering all segments The essential procedures in segmental resection are

1 The accurate dissection in the hilum of the supplying artery and bronchus

2 The ligation and division of the artery

3 The clamping of the supplying bronchus followed by the inflation of the remainder of the lobe by increasing the positive intratracheal pressure this allows the segment to be accurately delineated as it will remain collapsed unless there is considerable air drift (see p 10) At this stage great attention is paid to the intersegmental vein this should be defined clearly and not damaged if it is tied the adjacent segment becomes passively congested and there may be haemoptysis in the post-operative period in addition to functional loss

4 The division of the pleura along the line of the intersegmental plane

5 The application of traction to the forceps applied to the divided artery and bronchus and the peeling out of the segment from surrounding healthy lung tissue by a mixture of blunt and sharp dissection (Clagett and Deterling 1946 Overholt *et al* 1950)

6 The avoidance of clamps and unnecessary suture on the healthy lung tissue which at first allows air to bubble out of the damaged alveoli but these soon become self-sealed.

The use of clamps causes unnecessary trauma to healthy lung tissue while suture of the raw areas may cause great loss of expandible lung tissue and considerable distortion of the lobe

7 The ligation and division of the vein or veins that are clearly seen during the course of the "peeling" out of the diseased segment

The operation of segmental resection. The pre-operative attention, the position of the patient and the type of anaesthesia used are governed by those principles that obtain for lobectomy The commonest segments to be removed are those of the lower lobe and the lingula

Resection of the basal segments, conserving the apical segment. Excision of the lingula has been described on page 172 This is through the intercostal space between ribs 6 and 7, a lower incision than this hinders easy access to the lung hilum When the retractors are in place and any obstructing adhesions have been divided, the first step is to display fully the hilum in the great fissure If the lower lobe segments are to be resected and the apical segment of the lower lobe is to be saved, the posterior limit of the great fissure is fully exposed by retracting the two lobes by means of pledgelets held on long artery forceps Adhesions in the fissure are carefully divided and the adventitia over the pulmonary artery is held up and freely divided With careful dissection the loose areolar tissue is well cleared from the artery If the apex of the lower lobe is depressed downwards the first branch to be seen is the one proceeding to the apical segment the main pulmonary artery continues downwards into the mass of the lower lobe Sometimes one single vessel can be cleared, tied and divided between two ligatures, but frequently the main artery gives off the branches separately and early and when this is the case they are dealt with seriatim If, as is so often the case, the lingula on the left and the middle lobe on the right have also to be resected the next step of the operation is to define, isolate, tie and divide their vessels, typically they arise from the main stem in the fissure almost opposite to the branch to the apical segment

When the arteries have been divided the bronchus is seen this requires to be cleared meticulously especially on its postero-lateral aspect, because here will be found the vein draining the apical segment that is to be conserved The bronchus is then (there is 1 cm of it below the origin of the apical segment bronchus) clamped just below the point of origin of the apical segment and the lower lobe is held upwards and medially while the operator turns his attention to the posterior surface of the lobe and divides the pleura freely over the inferior pulmonary vein This is freed deliberately of all fascial and areolar envelopments until the entry of the vein from the dorsal lobe is seen clearly and this must, of course, be preserved When the other tributaries of the vein have been secured and divided the anaesthetist inflates the lung until the air has distended the dorsal lobe this will demonstrate the point at which the airless lung of the segments whose bronchi have been clamped and divided meets the air-filled dorsal lobe Along this line the pleura is incised and then the lower lobe segments are peeled off the healthy tissue of the dorsal lobe by a mixture of blunt and scissor dissection When this has been achieved the lobe is only held by the ligamentum latum which is divided after its vessels have been clamped the bronchus is closed in the usual way by means of the open bronchus technique

Occasionally one segment only of the lower lobe requires resection, if this is so the artery and bronchus to the segment to be resected are carefully dissected The segmental bronchus and its artery are divided before any attempt is made to isolate the vein Once traction is applied to the forceps on the distal end of the divided bronchus the segment begins to peel out and the vein will be seen quite clearly and can be seized and divided

Resection of upper lobe segments The anatomical approach to these segments is described on page 10 The essential features are the exact display of the segmental artery and bronchus before any attempt is made to secure and divide them.

The post-operative treatment The principles of the post-operative management after resections are discussed in Chapter V and pages 221 222

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PART III

PULMONARY TUBERCULOSIS

CHAPTER 9

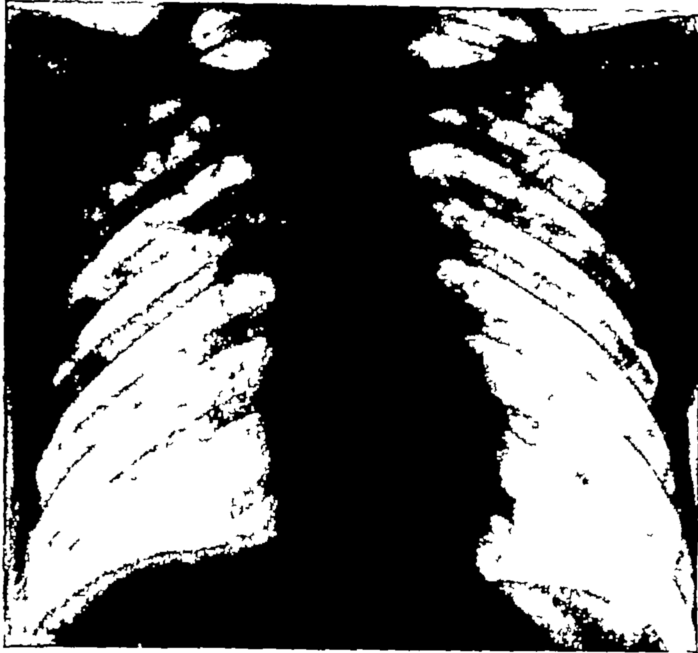
Introduction

The anti bacterial agents streptomycin, P.A S and isoniazid employed in combination to enhance their activity and delay the development of resistant strains of the tubercle bacillus have completely altered the clinical management of pulmonary tuberculosis At the time of writing these drugs are being used for long periods up to or beyond two years and with such apparent effectiveness that fewer surgical operations are being performed and these often on patients with a negative sputum or one with bacilli so altered that they do not grow on the conventional media used in the laboratory In most instances now we are operating more with the object of preventing later relapses rather than with the previous aim of making efforts sometimes defective and hazardous to save life by the closing or removal of cavities carrying a persistent threat to the patient because they harboured active dangerous bacilli

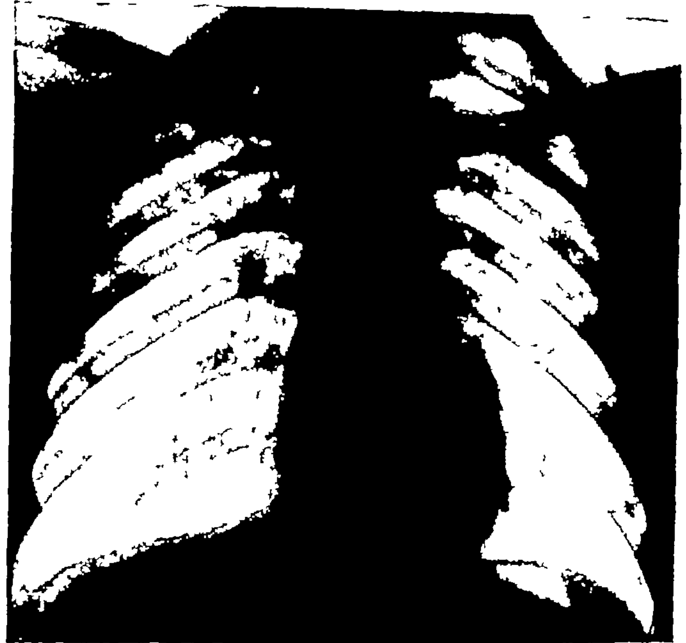
The present position of surgery

In the justified wave of optimism about the future of tuberculosis the rapid decline in mortality rate has not yet been accompanied by such a comparable fall in notification rates though this is likely to be more marked in the next few years The effective treatment of acute and subacute disease by the anti bacterial agents should see a great decline in the number of patients requiring surgery but it is salutary to remember that in 1953 alone 340 416 new cases were notified in the U S.A Great Britain France and Germany (Drolet 1955) and that surgeons are being shown a great number of patients with irreversible changes or masses of caseous tissue which in our present state of knowledge require surgical treatment either by resection or collapse

The selection of patients for surgery has become a more perplexing problem since long term effective chemotherapy has been used for the previous criterion of a positive sputum is no longer the main pointer to the need for collapse therapy or excision in chronic disease most cavities can be decreased in size or made to close by streptomycin bed rest and postural retention (Dillwyn Thomas) Relapse however is not infrequent and we remain in ignorance as to the future behaviour of serious tuberculous lesions that have been effectively treated and appear quiescent It is this doubt that has impelled Medlar 1955 (a pathologist who has studied this disease through all its modern evolution) to persist in his belief that surgery is often the safest climax to the treatment of cavities and solid foci after effective treatment by bed rest and chemotherapy In re writing this chapter I am in the difficulty of attempting to describe events that are moving rapidly but which are far from a final solution Some of the material presented has a historical flavour and refers to problems that do not appear frequently today in countries where the tuberculosis programme has been thorough none the less patients are still seen with gross cavitation and with extensive areas of destroyed functionless tissue which are a menace to life A further important group is provided by patients with symptomless



(a)



(b)

FIG 9 1

(a) Bilateral upper lobe disease

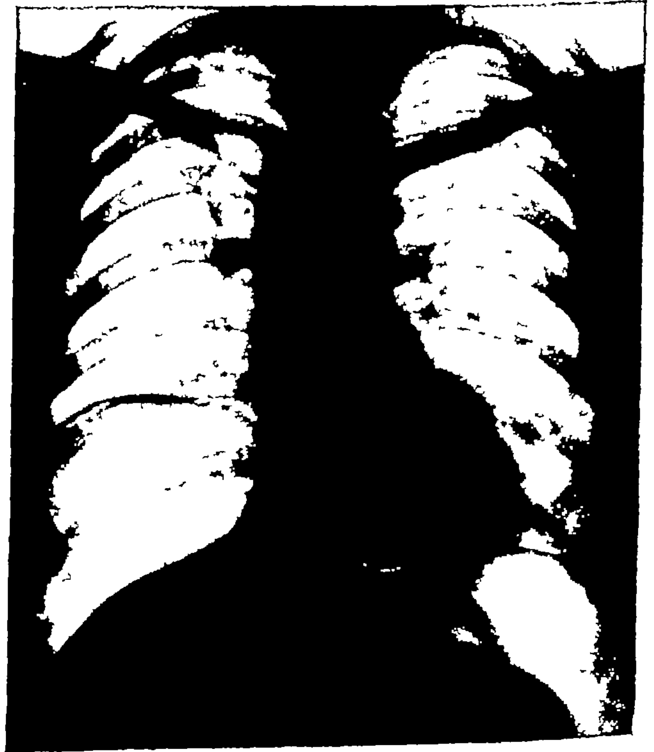
Acute type with multiple cavitation, patient toxic and pyrexial

(b) Radiograph of patient illustrated in Fig 9 1 (a) after one year's complete bed rest, six months of which were spent in a plaster cast

Considerable resolution with minor cavitation in right upper lobe now amenable to surgery This patient was treated before the streptomycin era



(a)



(b)

FIG 9 2

(a) Right upper lobe, exudative disease, with a cavity below the clavicle

Patient toxic and pyrexial

(b) Radiograph of the same patient illustrated in Fig 9 2 (a) after bed rest, right phrenic nerve crush and a pneumo peritoneum (treated before streptomycin was available)

Notable healing and cavity disappearance

opacities consisting of masses of caseous material usually blocked cavities, which may erupt Their resection segmentally may avoid lengthy treatment provide security and in the appropriate age groups exclude the possibility of these shadows being due to early carcinoma

Collapse therapy or resection?

Any who read the literature pertaining to the surgery of pulmonary tuberculosis appreciate the impossibility of answering this question with certainty It may indeed be unwise to compare two methods that have separate aims and objects Neither is employed except as part of a carefully planned regime in which rest general measures and chemotherapy play a major role either may be required when medical measures have failed to control the disease or when highly satisfactory treatment has left a permanent residuum of disease which physicians and surgeons believe may be a source of later relapse

In most surgical clinics thoracoplasty has been found to have a low mortality rate (1–2 per cent) with satisfactory follow up of results classified as between 80 and 85 per cent (i e with negative sputum and leading a useful gainful life) Moreover it is often used in less favourable cases than the resection group many of the patients having disease in upper and lower lobes and frequently on the other side to such a degree that resection might well be contra indicated It reduces respiratory reserve by about 20 to 35 per cent but this cannot be compared directly with the loss following resection where the result varies greatly depending on whether segmental resection lobectomy or pneumonectomy have had to be done (Thoracoplasty however has certain grave defects it is uncertain in its effects it is deforming, though far less so today than formerly may have to be done in stages and carries the risk of infection in the extracostal space It is moreover applicable only to upper lobe lesions except in exceptional circumstances (Fig 9 18) it is not satisfactory for the treatment of solid tuberculous lesions for lower lobe cavities or for examples of bronchiectasis or many cases of bronchostenosis)

Resection carries a higher mortality rate which is probably between 2 5 and 5 per cent though certainly lower in the hands of such great supporters of the operation as Edwards (1955) and Dillwyn Thomas (1954) and their colleagues (its main complication is the development of broncho pleural or bronchiolar pleural fistulae which may be serious) If however the question of disease of the apical and posterior segments of the upper lobe is omitted for the moment it is clearly the method of choice for cavities of the lower lobe and of the anterior parts of the lung elsewhere (the anterior segments the lingula or the middle lobe are notoriously difficult to treat by collapse therapy) for tuberculous bronchiectasis of severe extent and for most cases of destroyed lung with bronchostenosis and for solid round foci (tuberculoma solid caseous foci or blocked cavities)

In the treatment of upper lobe cavities the modern limited upper thoracoplasty still has a place especially in those patients where it is considered that lobectomy would require to be followed by a space-reducing upper thoracoplasty In such patients a trial thoracoplasty may well prove to be successful as a one-stage procedure so that lobectomy is not required (Thoracoplasty is much safer when resistant organisms are present)

Finally it may be said that the results of resection where the disease has been eradicated by a simple procedure such as a segmental resection without any complications ensuing are better functionally than the best of thoracoplasties good though these are

Effect on respiratory function of collapse measures

Any form of collapse therapy interferes with ventilatory function as can be demonstrated by the lowering of maximum breathing capacity thoracoplasty operations naturally

interfere with the movements of the chest wall and also with the full range of the diaphragm It might be assumed that this would have more serious effects on the respiratory function than artificial pneumothorax according to Gaensler and Strieder (1950), this is not so From their studies of the maximum breathing capacity, residual air, ventilation on exercise and the breathing reserve and using bronchospirometry findings they have established a valuable estimate of the effects of the different collapse procedures In a series of patients whose total ventilatory capacity was estimated six months after the induction of a pneumothorax, the loss was 30 per cent in the average patient it was only 15 to 12 per cent after lobectomy In the same group of patients bronchospirometry showed a loss of 50-60 per cent after pneumothorax, contrasted with 20–25 per cent after thoracoplasty After the operation of phrenic nerve interruption or extrapleural artificial pneumothorax the loss was 10–15 per cent A pneumothorax maintained for over a year greatly impairs ventilation and oxygen uptake

In assessing the loss of respiratory reserve after resection, the findings will depend on the extent of tissue removed, the final state of the pleural cavity and chest wall and diaphragmatic function and whether a thoracoplasty or phrenic nerve paralysis has been needed to complete the procedure The removal of one segment alone frequently leaves the respiratory function as good as it was before operation

The subject has been discussed more fully in Chapter 2

COLLAPSE PROCEDURES

The following collapse procedures have been used most are of historical interest only

(*A*) Intrapleural artificial pneumothorax
(*B*) Surgical division of adhesions in an artificial pneumothorax
(*C*) Interruption of the phrenic nerve
  1 Complete and permanent
  2 Temporary (phrenic crush)
  3 Combined with pneumo-peritoneum
(*D*) Thoracoplasty
(*E*) Extrapleural artificial pneumothorax
(*F*) Direct pressure collapse
  1 Plombage
  2 Oleo-thorax (p 250)

The more direct measures such as resection and cavity drainage will be discussed later.

INTRAPLEURAL ARTIFICIAL PNEUMOTHORAX

Artificial pneumothorax is rarely used today The aim is to provide temporary local rest to the lung, to decrease the size of the diseased area and to relax rather than compress it The early views attributed the beneficial effects of collapse therapy to immobilization and compression of the lung, and attempts were made to force the whole lung down to the mediastinum by the injection of air into an artificially produced pneumothorax, disastrous results both on the physiology of the patient and on the pleural cavity frequently followed The ideal is a selective relaxation of the diseased area which encourages the natural elasticity of lung tissue to produce a concentric shrinking of the diseased lobe or lobes Collapse can be achieved by artificial pneumothorax (Fig 9 3), local selective thoracoplasty (Figs 9 4 (*a*) and (*b*)), phrenic nerve interruption (Figs 9 5 (*a*) and (*b*)), pneumo-peritoneum (Figs 9 6 (*a*) and (*b*)), or extrapleural pneumothorax (Figs 9 7 (*a*) and (*b*))

In a satisfactory artificial pneumothorax the lung separates from the parietal pleura most widely in the area of maximum disease this area shrinks concentrically and the healthy lung tissue elsewhere because of its normal elasticity remains well aerated (Fig 9 3) This satisfactory result of a good pneumothorax in which the intrapleural pressures are left on the negative side follows if there are no adhesions between the parietal and visceral pleura and if the healthy lung tissue can remain *well aerated if adhesions are preventing* the collapse they may be divided surgically *(pneumolysis—see below) and the pneumothorax* made selective and perfect Atelectasis when it developed was fraught with danger

Atelectasis of a lung or lobe of a lung is dangerous for several reasons the common sequel *is that fluid develops within* the pneumothorax space (the same effect is common when atelectasis develops in other conditions e g post-operative massive collapse post

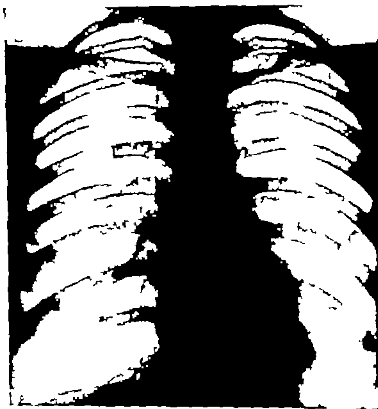


Fig 9-3 —An example of a selective artificial pneumothorax, relaxing a diseased right upper lobe and leaving the lower lobe well aerated.

lobectomy collapse etc) In tuberculous disease this fluid may become infected with tubercle bacilli and/or pyogenic cocci and the dangerous condition of pyo-pneumothorax is then present

The atelectatic area of lung *is itself a potential ground for serious mischief* the alveoli become full of exudate in place of air and the ciliary action of the bronchi is lost so that stagnation of bronchial secretions follow frequently with the rapid growth of organisms non tuberculous as well as tuberculous This is often reflected in the temperature chart which may show a rapid increase in pyrexia If the lobe remains airless for several weeks its bronchi dilate and irreversible bronchiectasis may follow

Atelectasis within an artificial pneumothorax readily seen on radiological examination requires urgent correction Sometimes *an immediate adjustment of the pleural pressures*

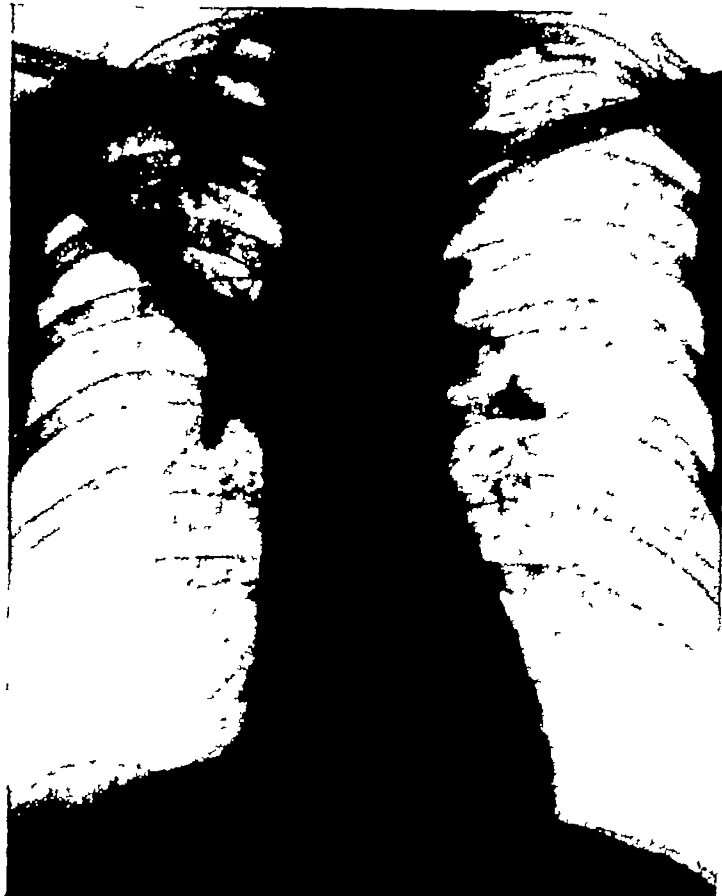




FIG 9 4

(a) Cavity in right upper lobe, partial atelectasis the result of endobronchial disease

A case for resection could be made out, but this could still be carried out if a thoracoplasty failed to close this cavity Fig 9 4 (b) shows that the thoracoplasty sufficed

(b) Selective upper thoracoplasty for cavity illustrated in Fig 9 4 (a)

Sputum negative six years after operation



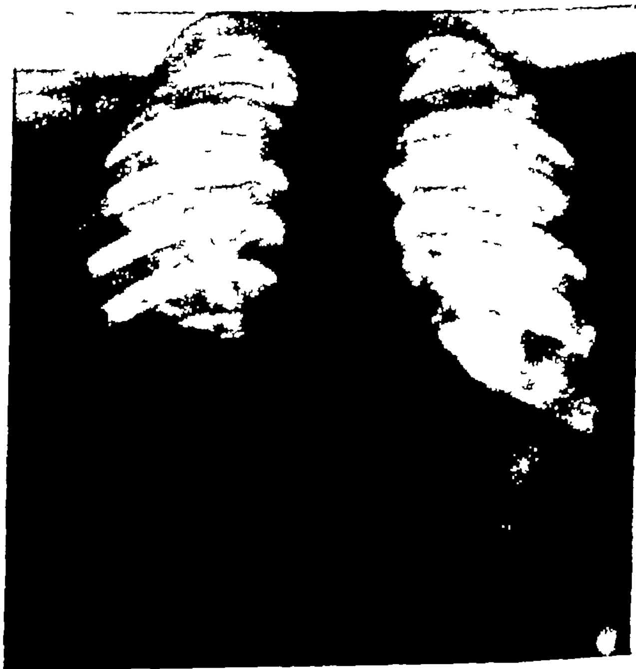
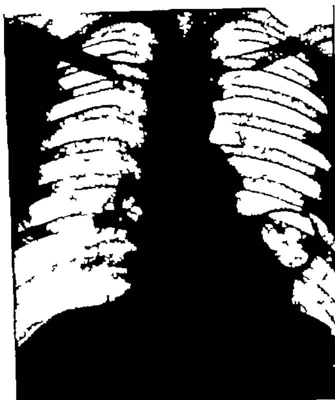


FIG 9 5

(a) A right phrenic nerve crush has been done for a large lower lobe basal cavity in a child of 14

(b) The effect provided by the elevation of the right leaf of the diaphragm in the patient whose cavity is seen in Fig 9 5 (a)

The cavity was proved closed by tomograph and the sputum has remained negative This radiograph was taken a year after that shown in Fig 9 5 (a) The lower lobe became atelectatic and required resection no tubercle bacilli were present





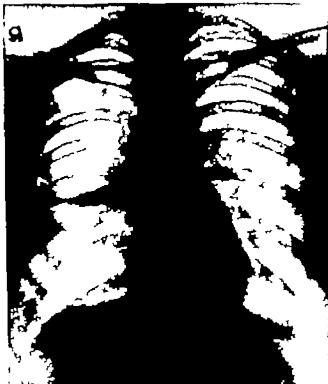
(*a*) (*b*)

Fig 9-6

(*a*) Left lower lobe cavity

(*b*) Selective collapse of left lower lobe cavity after left phrenic crush and pneumo-peritoneum. The temporary result is excellent but today prolonged chemotherapy possibly followed by resection, would be preferred.





(*a*) (*b*)

Fig 9-7

(*a*) Right upper lobe cavity associated with endobronchial disease

(*b*) Right upper extrapleural artificial pneumothorax employed for the cavity demonstrated in Fig 9-7 (*a*). The collapse is selective and efficient but could be criticised for the temporary type of collapse provided for a lesion calling for permanent collapse the patient however is in satisfactory state now for upper thoracoplasty (pre-streptomycin case).

may lead to prompt re-expansion, but if this is not achieved the artificial pneumothorax should be abandoned and other measures considered

It is important to realize the danger of atelectasis in a pneumothorax because in former days we were encouraged to believe that bronchial occlusion of a lobar bronchus would often cause a cavity to disappear This was true enough, but the associated risk of the cavity rupturing if the atelectasis is within an artificial pneumothorax is obvious A study of these patients showed that a collapsed segment or collapsed lobe in an artificial pneumothorax was dangerous if the sputum was positive or a cavity was present

All the criticisms of artificial pneumothorax expressed here may not be applicable today because it is unlikely that any patient would be submitted to pneumothorax therapy unless active disease had been fully controlled by chemotherapy and a bronchoscopy had been performed to exclude endo-bronchial disease, the cause of atelectasis I know of no large series of patients treated by pneumothorax combined with streptomycin therapy It is probable that many of the complications described here would not be seen under such conditions

A constant review of all types of collapse seen within a pneumothorax in the last twelve years has provided convincing evidence of the serious dangers of atelectasis There are far safer methods of treatment now available if thoracoplasty, resection procedures and the correct use of antibiotic therapy are applied rationally and safely

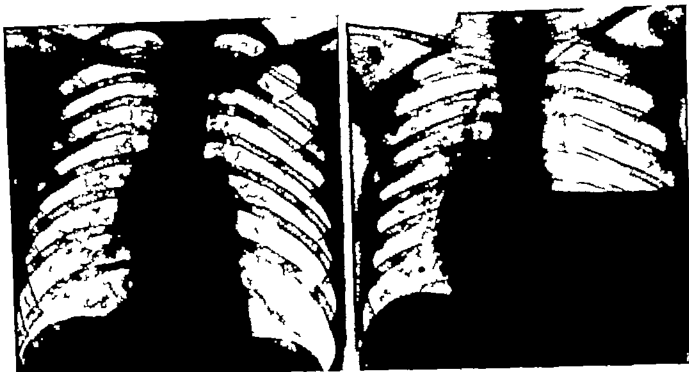
The radiological story shown serially (Fig 9 8) describes the series of changes that followed in a boy of 19, treated by artificial pneumothorax for a small tension cavity in the left upper lobe The first radiograph demonstrates a segmental collapse in the left upper lobe with a small cavity still apparent at the base of the atelectatic mass , the right course would have been to abandon the pneumothorax, probably with a small upper thoracoplasty or resection as the ultimate treatment A month later the common complicating catastrophe of massive collapse of the whole lung with fluid formation in the pleura had occurred

Attempts to obtain re-expansion failed and a total empyema developed which required frequent aspirations, the fluid containing tubercle bacilli , the intrapleural pressures became positive a few hours after each paracentesis, evidence of a broncho-pleural fistula After several months of illness the chest was opened, the lower lobe decorticated and a left upper lobectomy carried out It was obvious from the operative finding that a cavity in that upper lobe had ruptured into the pleural cavity The lower lobe re-expanded and an upper thoracoplasty was then performed to diminish the size of the left hemithorax , progress was slow but satisfactory and entailed an 18 months' stay in hospital which, combined with many aspirations and three major operations, was a heavy price to pay for an injudicially maintained pneumothorax Today chemotherapy would probably suffice

Endobronchial disease as a factor producing atelectasis

Atelectasis in patients with a positive tuberculous sputum may be seen in a segment, a lobe or the whole lung , in primary tuberculosis a collapsed lobe may be produced by bronchial occlusion caused by gross pressure from enlarged tuberculous glands or from their ulceration into its lumen The dangers of atelectasis in a pneumothorax have been mentioned Collapse of the parenchyma of a lung may be due to endobronchial tuberculous granulation tissue Tuberculous bronchitis may be present in the absence of radiological changes in the lung and is a rare but important cause of a positive sputum under such conditions Such lesions can often be detected by bronchoscopy

Endobronchial disease is present in patients with " tension " cavities , the disease may be well away from a lobar or segmental bronchus, affecting only the bronchus draining the



(a) (b)



(c)

Fig 9-8

(a) Segmental atelectasis in left upper lobe within an artificial pneumothorax: note a healthy well-aerated lower lobe and small cavities in the collapsed segment

(b) A positive pressure tension pneumothorax with total atelectasis of the left lung has developed suddenly a month after the state of affairs depicted in Fig 9-8 (a)

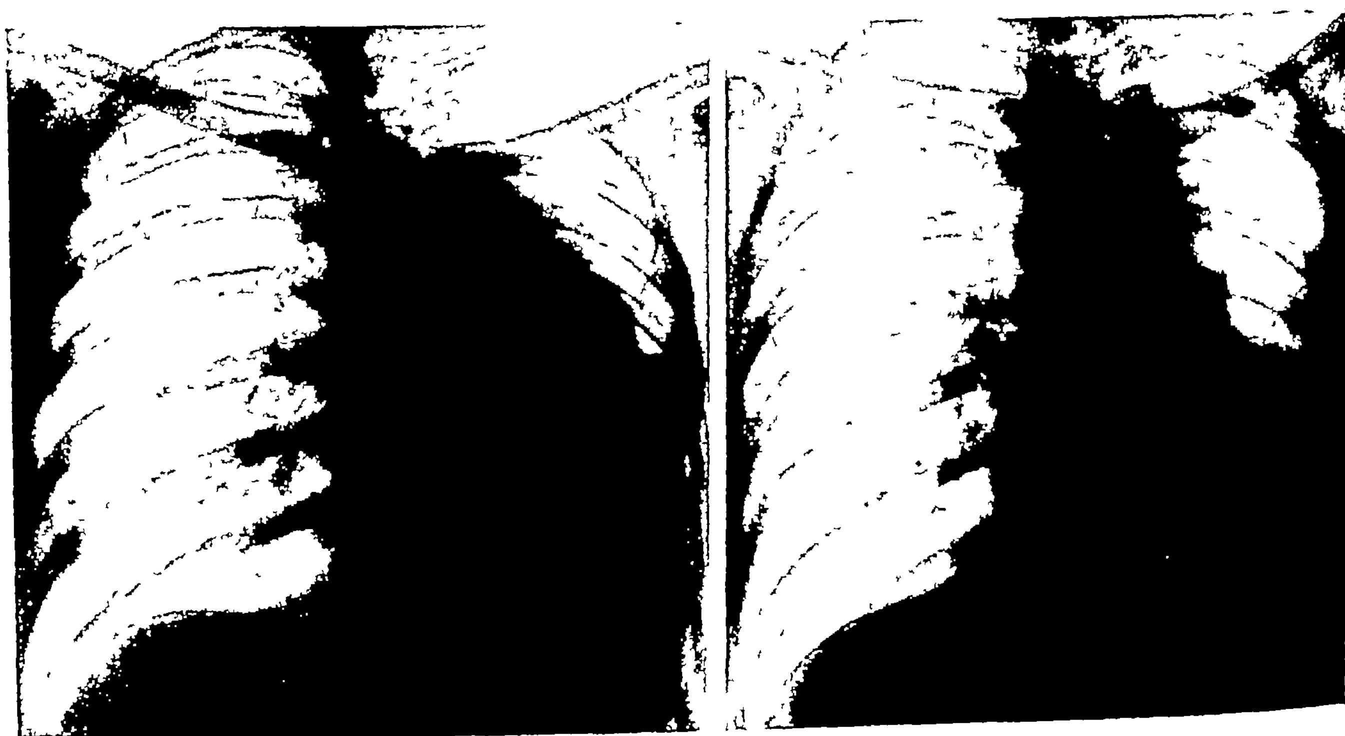
(c) The position has been largely retrieved by left lower lobe decortication left upper lobectomy (at which the cavity was seen to be ruptured into the pneumothorax space) and left upper thoracoplasty Film taken a year after Fig 9-8 (b). Treated in the pre-streptomycin era

area of cavitation In such the endobronchial lesion acts as a valve mechanism by reason of its oedematous granulation tissue During inspiration the bronchi dilate and air can pass into the cavity With expiration the bronchial wall contracts and the lumen, already partially filled with tuberculous tissue, narrows to such a degree that the air entrapped in the cavity cannot escape and a tension or balloon cavity develops (Coryllos and Ornstein, 1938 , Price Thomas, 1942) The use of artificial pneumothorax in such a patient may increase the effects of this ball-valve mechanism and the cavity will often enlarge under the influence of the increasing air pressure Prolonged chemotherapy has a profound effect on this type of lesion, either by leading to the disappearance of the bronchial disease or by sterilizing the cavity Many such cavities on removal are smooth-walled and free from bacilli

Rafferty's *condemnation of artificial pneumothorax as a treatment* for lung disease associated with bronchial lesions has led to an almost complete disappearance of empyemata in sanatoria in this country and to the prompt recognition of atelectasis and its correction as soon as possible when it develops within a pneumothorax (Rafferty, 1943)

Endobronchial disease as the cause of bronchiectasis

A severe *tuberculous bronchitis may produce such stenosis of a main* bronchus or of a lobar bronchus that gross bronchiectasis of the lung or the lobe ensues This is usually seen in long-standing disease and often there is an associated cavity It was commonly seen when a pneumothorax has been induced for a cavity due to endobronchial disease which did not respond to the treatment , in this type of disease the previous aerated lobe or lung becomes atelectatic and fluid develops in the pleural cavity These patients may require resection operation if the other lung is sufficiently stable to allow this radical measure



(a) (b)

Fig 9 9

(a) Atelectasis of left lung in a pneumothorax
Bronchial tuberculosis in main bronchus effusion in pleural cavity
(b) After left pneumonectomy

The recognition of bronchial disease

The use of bronchoscopy before employing surgery is an obvious help but apart from this certain clinical and radiological features are of value

An element of a wheeze in the cough is often unduly troublesome and frequently non production of sputum is noteworthy the symptoms are more severe than the radiograph would indicate probably because of the effect of sputum retention distal to the lesion. Occasionally in bronchial disease the sputum is positive and yet there is no radiological indication of its source The X ray photographs may show an area of collapse often segmental and often mistaken for interlobar thickening or effusion and there is frequently a definite increase of shadowing in the peri hilar region (the hilar flare)

(If the bronchial disease clears with a regime of bed rest combined with a course of streptomycin and para aminosalicylic acid collapse by thoracoplasty if the disease is in the upper lobe may be preferable to resection unless bronchoscopy reveals a really healthy mucosa)

The treatment of parenchymal lesions associated with bronchial disease

(*a*) *Bed rest and chemotherapy* For lesions that might heal without collapse or resection procedures bed rest should be enjoined Streptomycin and chemotherapy is rarely withheld today from a patient requiring active treatment if surgical treatment may be required at some stage it is important to remember throughout that the presence of drug fast bacilli at the time of operation adds a hazard that can be avoided if such therapy is always controlled bacteriologically and by the persistent use of two and never one of the effective agents streptomycin P.A S and isoniazid

(*b*) *Operative treatment* This is often indicated if cavities remain open or become blocked under conservative treatment Tomography is always required to support the plain X rays study before it can be assumed that closure is complete The tomogram will often show a persistent cavity or a wide bronchus leading to a mass of caseous material These residua of medical treatment are potentially dangerous and carry the risk of later relapse unless thoracoplasty or resection is employed Such permanent measures have quite supplanted artificial pneumothorax as they are definite and permanent

Thoracoplasty has an important role in the treatment of upper lobe disease if the extent of the thoracoplasty required is not extensive and the modern operation is indeed a limited selective one

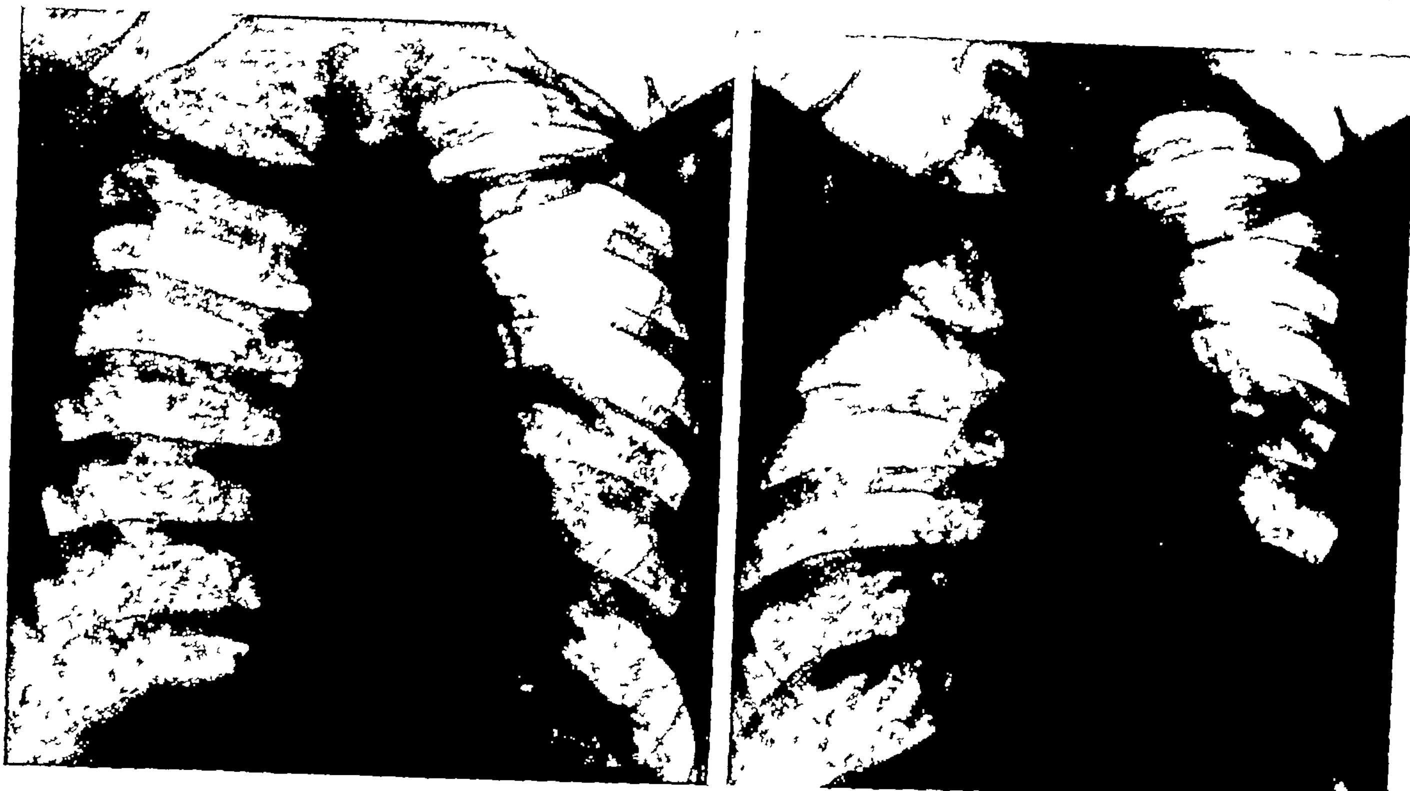
A cavity in a collapsed upper lobe is often best treated by lobectomy usually followed by a small thoracoplasty to prevent over-distension of the remaining lower lobe an upper thoracoplasty may be employed as the first procedure to be followed by lobectomy if the cavity remains open

For lower lobe cavities due to endobronchial disease thoracoplasty is quite unsuitable and if a temporary phrenic paralysis with pneumo peritoneum fails to close the cavity lobectomy or segmental resection is indicated in the absence of obvious contra indications such as prohibitive disease in the upper lobe or in the other lung such contra indications may disappear with bed rest and streptomycin therapy

Indications for artificial pneumothorax

It is difficult today to find a patient in whom artificial pneumothorax has been induced within the last three years It is possible that for a strictly limited period of a few months a pneumothorax might be induced for disease of a limited nature on the good side in

a patient awaiting surgery on the other lung for serious disease Adequate chemotherapy, however, in most instances will clear such lesions within three to six months Theoretically a patient who has relapsed and who has drug resistant bacilli might be considered for this therapy but I have no evidence in fact that this is being done It must be reluctantly admitted that at last a treatment, of great value before the development of chemotherapy, has become obsolete In modern therapy we are therefore concerned only with a discussion of the problems that may still exist many years after a pneumothorax had been induced



(a) (b)

Fig 9 10

(a) Although far from being an ideal left pneumothorax, a cavity in the left upper lobe has been controlled sufficiently to allow a small thoracoplasty to be done for the right upper lobe cavity
(b) The right upper lobe cavity seen in Fig 9 10 (a) has been closed by a small thoracoplasty

The complications of a pneumothorax

In former days these were frequent, consisting largely of fluid formation, sometimes proceeding to tuberculous empyema, the development of a spontaneous pneumothorax and the failure of the lung to re-expand after the treatment had achieved its object They were largely due to the faulty selection of patients for pneumothorax, i e acute disease, endobronchial tuberculosis, the failure to abandon the treatment when atelectasis developed or when adhesions were left undivided A brief consideration of the treatment of these complications may be useful as in some parts of the world pneumothorax therapy may still be used where antibiotic and chemotherapy is not available

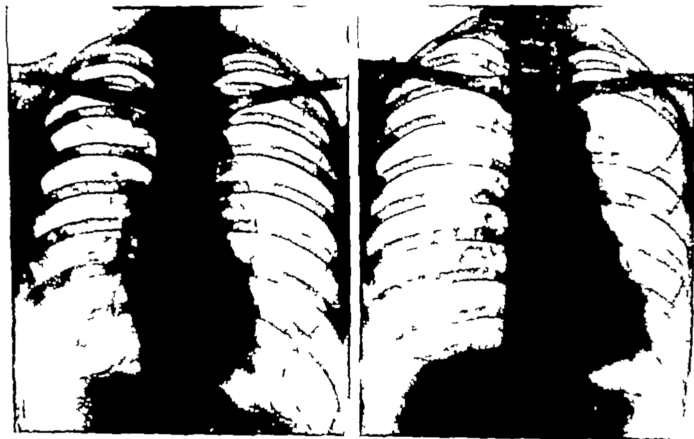
The treatment of the complications of pneumothorax

Effusions Pleural effusions may develop before or after adhesion section, the transient, innocuous ones being treated by aspiration but the rapid re-accumulation of fluid is an indication for re-expanding the lung, as the dangers of pyopneumothorax or of inexpandable

lung are great (see p 190) The treatment of tuberculous empyema is long and difficult and is discussed in the next chapter

Spontaneous pneumothorax Spontaneous pneumothorax into a pneumothorax space is usually due to rupture of an emphysematous area in the collapsed lung often in association with adhesions After the immediate ill-effects have been treated by repeated withdrawals of air or the use of an in-dwelling needle leading to a water-sealed drainage system a thoracoscopy is indicated and at this examination any adhesions leading to affected areas of lung are divided, as frequently the air leak comes from a tear in the lung parenchyma at their base If there is extensive emphysema present the pneumothorax should be abandoned and this may have to be achieved by the use of chemical pleurodesis (see p 531) If an empyema develops it is dealt with as described on page 241

Haemothorax A spontaneous haemothorax is a rare but serious complication which



(a) (b)

Fig 9-11

(a) Radiograph of a woman of 29 five years after a pneumothorax had been induced. All attempt t [illegible] re-expansion had failed.

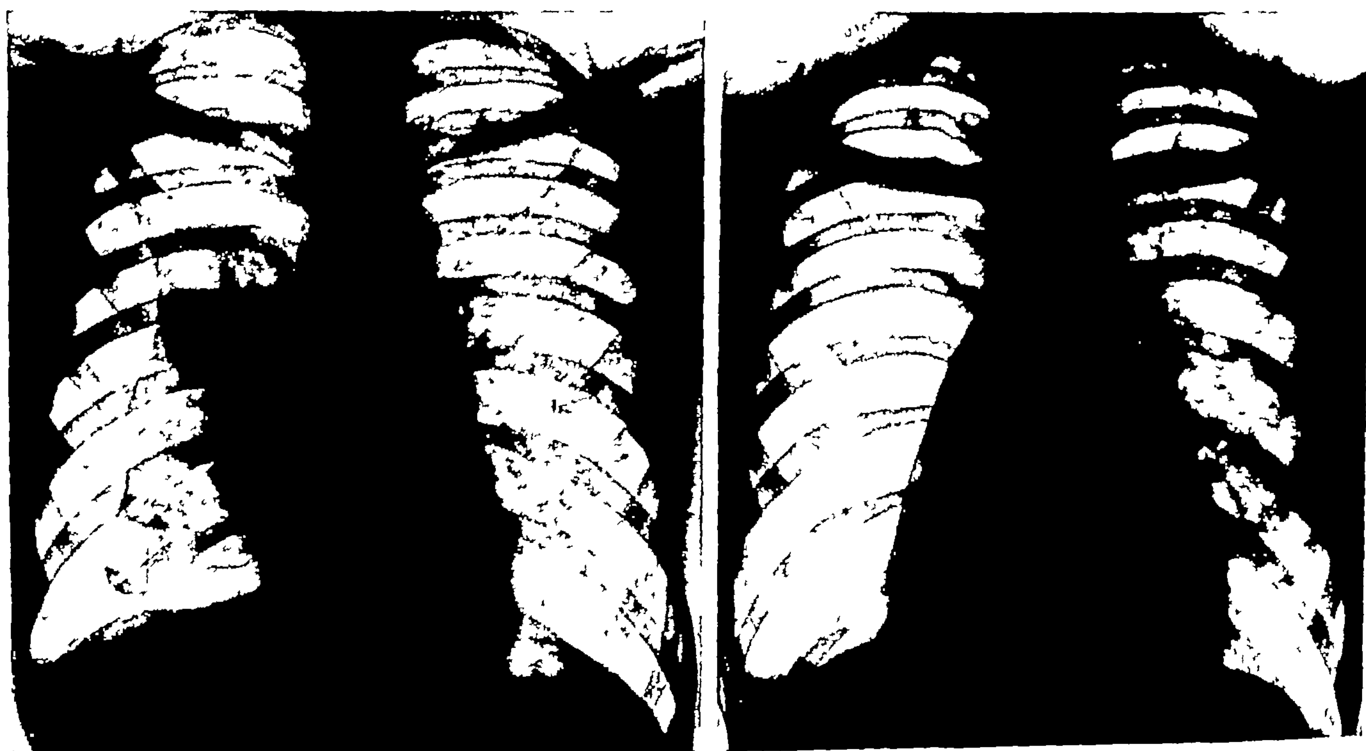
(b) One year after decortication: the lung has fully re-expanded. It function is no doubt poor but the dangers of [illegible] empyema [illegible] the need for repeated re-fills hav been [illegible] voided.

accompanies the tearing of undivided adhesions In the first 12–24 hours the treatment is quiet enforced by the use of morphia and absolute rest if the haemoglobin falls below 70 per cent a slow blood transfusion is set up After this period the haemothorax fluid should be aspirated and the pneumothorax usually abandoned If however the haemothorax is small and easily dealt with by aspiration thoracoscopy will be indicated if there are adhesions still present and the reasons for continuing the pneumothorax are sound A

temporary phrenic crush and a pneumo-peritoneum may be required if the lung will not re-expand rapidly, when a decision has been made to abandon the pneumothorax

Atelectasis The development of opaque, airless lobes or segments must be regarded as a complication and the seriousness and treatment of this has been discussed If atelectasis develops rapidly the intrapleural pressures may require immediate re-adjustment, as alteration of the line of the bronchus may lead to immediate re-aeration If the rapid development of an opaque lobe is associated with pyrexia, bronchoscopic suction is often indicated whether the patient is undergoing pneumothorax treatment or has just been operated on for the performance of a thoracoplasty or resection

The unexpandable lung Since the aim of pneumothorax treatment is a temporary selective collapse which allows the lesion under consideration to heal, the failure of the lung to re-expand when healing has occurred must be regarded as a complication which indeed may be followed by an empyema, and by emphysema of the opposite lung which may cause a late fatal cardiac condition (Cor pulmonale)



(a) (b)

FIG 9 12

(a) Atelectasis of right upper lobe with a cavity and a "free" lower lobe
Dangerously tempting for adhesion section!

(b) Same case four months after adhesion section
Although the cavity has closed the right lung is atelectatic and in great potential danger, a better result would have followed re expansion of the A P and an upper thoracoplasty (a pre-war patient)

Unexpandable lungs are due (1) to faulty selection of patients in which a temporary collapse method has been used for a lesion requiring persistent collapse or resection, (2) to the presence of endobronchial tuberculous disease which contracts to produce a broncho-stenosis, or (3) to the development of a thick cortex or organized fibrinous material in the pleura this is often associated with an empyema and the treatment of this by pulmonary decortication or thoracoplasty is considered later

The lung may fail to expand because of stenotic tuberculous bronchial disease or

because of extensive parenchymal disease and it may be wiser to proceed to thoracoplasty than to allow the lung and mediastinum to swing right over when the pneumothorax is abandoned Stenotic bronchial disease causing a bronchiectatic or destroyed lung often requires a pneumonectomy

Whether the lung is unexpandable from avoidable or unavoidable causes it is unwise to attempt re-expansion if this can only be achieved by gross displacement of the mediastinum to the treated side as this may lead to severe dyspnoea and over-distension of the good lung The decision should then be made as to whether the pneumothorax should be maintained indefinitely or be replaced by a permanent thoracoplasty aided occasionally by a decortication of the underlying lung A pneumothorax so maintained may be satisfactory and patients have been maintained in comfort and health for periods of ten years and longer the development of fluid however slow is a serious sequel and usually indicates the need for major surgery Such operations will be imperative if the fluid becomes purulent

The development of a thick organized fibrinous envelope over the collapsed lung may be the cause of failure to re-expand and under certain rigidly established criteria the ideal treatment may be a lung decortication (Fig 9 11)

Such a measure will only be considered if the lung parenchyma is good the sputum negative and the pre pneumothorax radiograph showed a localized extent of disease noted on later films to have been rapidly controlled by the pneumothorax

Thoracoscopy

The division of adhesions in tuberculous patients by the thoracoscope has disappeared from the operation list Thoracoscopy is only employed today for diagnostic reasons and

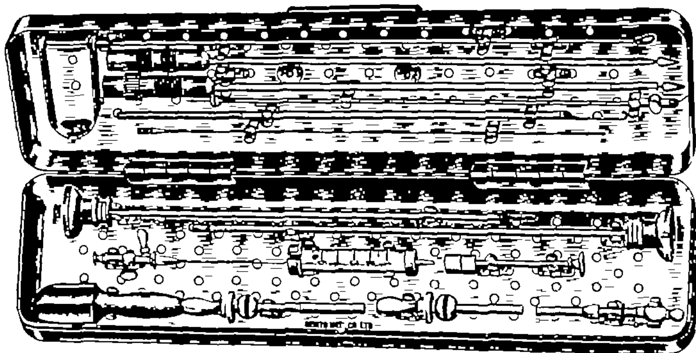


Fig 9·12 —Double puncture thoracoscope

for the treatment of recurrent spontaneous pneumothorax (Chapter 21) in which the division of adhesions leading to the area of bullous formation responsible for the pneumothorax may lead to rapid closure of the area of leakage of air

The operator has the choice of two instruments

(*a*) The Single Puncture Thoracoscope
(*b*) The Double Puncture Thoracoscope

The double puncture method. Rather outweighing the popularity of the single puncture instrument, the use of two cannulae, the original plan of Jacobaeus the pioneer of thoracoscopy is more favoured, because of the wider range of vision and the larger field of intrapleural manœuvre that is attainable (Fig 9 13) These factors and the availability of either cannula for vision or for introducing the cutting instrument perhaps makes the division of multiple adhesions safer the operator too can often determine more readily whether he can divide safely because both the

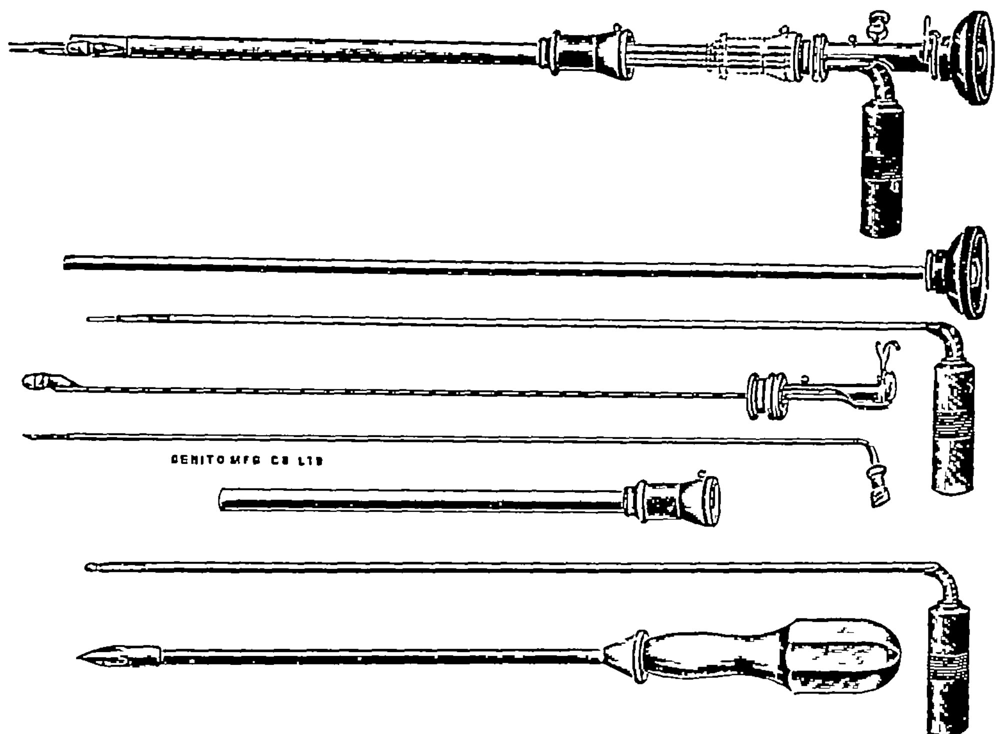


Fig 9 14 —Single puncture thoracoscope

front and the back of the bands can be seen Apart from the need to employ two small puncture holes the apparatus is simpler than the single puncture instrument and less prone to break down because of this If bleeding follows the division of an adhesion by the single puncture instrument the lamp is more readily clouded by blood, a disadvantage easier to avoid with the double instrument technique

Technique of adhesion division. In most instances the adhesions are situated posteriorly and a pre-operative estimate of their size and position is attempted by a study of the radiographs and by screening But the true nature of the bands and an opinion as to divisibility can be made only at the thoracoscopic examination Usually the patient lies on the normal side with the head of the table raised and pillows arranged in such a way that the uppermost side of the chest is convex The site selected for the puncture varies with each pneumothorax, but usually the first cannula should be introduced in the sixth intercostal space posteriorly just behind the angle of the scapula The skin and pleura having been anaesthetized by the injection of 2 per cent procaine, an artificial pneumothorax needle is introduced to confirm the presence of an adequate pneumothorax space free from adhesions these or a too distended lung can be detected readily when the stilette of a re-fill needle has been passed beyond the opening at the needle end

Into the space a cannula mounted on a trocar is introduced and the telescope then replaces the trocar if this has been previously warmed in hot water and rapidly wiped dry, fogging will not develop on the lamp , if the view is misty it will clear after a few moments when the normal warmth of the pleura has ceased to act Other causes of a hazy view are blood on the lens, or because the telescope is touching adhesions or lung itself

A complete survey of the pneumothorax should be made before the second cannula is introduced

and the surgeon will decide on the possibility of adhesion division If the adhesions are surgically divisible the section should be made as close to the chest wall as possible to avoid damage to lung tissue



FIG 9-15 —Thoracoscopy by the two cannula method. The patient i lying on the left side

The cutting agent employed is the cautery and not the diathermy current the latter coagulates a wide area of tissue and the range of necrosis so produced may run on into lung tissue which might slough to produce a fistula and consequent empyema Bleeding from the adhesion on the chest wall side can be checked by applying diathermy but usually cautery at dull red heat suffices and causes less pain to the patient

Before apical adhesions are divided inspection of the dispositions of the subclavian vein and artery and of the azygos vein on the right must be made before the bands are sectioned In the literature occasional disasters of haemorrhage have been recorded following injury to the subclavian vein Because of the occasional risk of severe bleeding a standard thoracotomy set of instruments should be laid out in preparation for rapid action which may be necessary

At the end of the adhesion section the lung is allowed to re expand partially by allowing air to escape during a few breaths by removing a finger from the end of the cannula during expiration The puncture wound is then closed by a single suture and a firm strapping applied over the area

Post-operatively the patient should be propped up preferably lying towards the operated side A radiograph is taken 12 hours after the thoracoscopy and the pneumothorax adjusted according to the radiological findings Cough should be checked as much as possible for the first 24 hours unless atelectasis has developed, and for this reason the patient should be nursed in isolation and all unnecessary talking and moving avoided. The clinical condition is frequently re assessed so that bleeding can be readily diagnosed if of any severity

PHRENIC NERVE INTERRUPTION

The great decrease in the use of this minor or auxiliary method of collapse therapy followed dissatisfaction with the results of its use and more especially because a permanent diaphragmatic paralysis may be a grave disability in patients who develop serious lesions in the other lung or who require a thoracoplasty on the same side

A physiological objection to phrenic paralysis is the loss of function in the lower lobe after the operation in modern thoracoplasty only the upper ribs are sacrificed to leave

a normal functioning lower lobe, and this ideal is seriously interfered with by a hit-and-miss phrenicectomy done previously in the hope (occasionally fulfilled) that an upper lobe lesion would be benefited.

Of its occasional assistance in the treatment of individual patients there can be no doubt and every tuberculosis physician can point to odd patients where lives have been saved by phrenic nerve interruption But as a treatment of cavities, wherever situated, it has proved disappointing when used alone, combined with artificial pneumothorax or pneumo-peritoneum it proved its value (It does not usually influence thick-walled, chronic cavities, and is contra-indicated in patients with upper lobe cavities associated with bronchial disease, detected either bronchoscopically or by the typical radiological appearances of that lesion) (It should not be used in dyspnoeic patients, especially in the older age group, as it may cause serious respiratory embarrassment by sacrificing the function of useful respiratory tissue)

In phrenic nerve interruption the paralysis should be of the temporary type until its beneficent action has been proved by the results in the individual patient when a conversion to a permanent paralysis may be justified, but as commonly done the "phrenic crush" is followed in over 25 per cent of patients by permanent diaphragmatic paralysis To lessen the risks of permanent paralysis after the "crush" operation the nerve should not be lifted from its sheath and should be crushed with reasonable gentleness so that nerve regeneration will follow (Although scarcely ever employed as the sole measure, phrenic nerve interruption still has a place in combination with pneumo-peritoneum, as a means of diminishing the size of the hemi-thorax after resection operations and at the conclusion of pneumothorax therapy)

Phrenic nerve interruption with pneumo-peritoneum is indicated when an upper lobe cavity suitable in itself for thoracoplasty, is complicated by exudative lower lobe disease, such a condition is employed as a measure preparatory to the thoracoplasty and may lead to the closure of the upper lobe cavity (Fig 9 16)

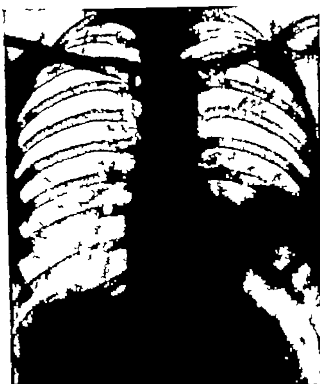
The operation for interruption of the phrenic nerve

This is performed under local anaesthesia with the patient lying supine on the operating table, with a small sandbag under the shoulders and with the head and neck rotated to the opposite side A small horizontal incision, 2 5 cm in length, is made in the posterior triangle of the neck, two finger's breadth above the clavicle and slightly overlapping the posterior margin of the sterno-mastoid

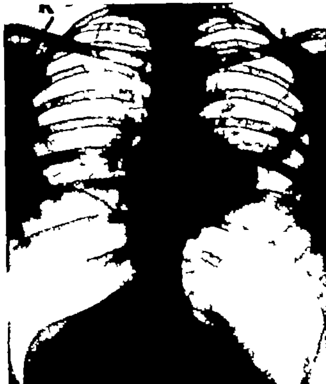
The skin and platysma are divided, the remainder of the operation from that stage being executed by blunt dissection, using a fine pair of artery forceps The posterior border of the sterno-mastoid is fully exposed and held medially by a small illuminated retractor in the posterior margin of the wound the external jugular vein is demonstrated and retracted laterally The assistant exerts an upward traction on the sterno-mastoid while the operator clears the underlying space by blunt dissection The scalenus anticus muscle covered by a fibro-fatty layer is cleared thoroughly and the phrenic nerve found lying on its anterior surface proceeding in an inward and downward direction just under the sheath of the muscle In the inferior part of the wound care is taken to avoid damaging the plexus of veins, while more superiorly the transverse cervical artery and its accompanying vein will be clearly visible At the medial end of the wound the internal jugular vein may be seen, slightly external and deep to it lies the cervical sympathetic nerve at the innermost edge of the scalenus anticus It is quite different in appearance from the phrenic nerve At the posterior end of the wound the brachial plexus will be seen emerging

eep to the scalenus anticus In many patients a careful search will reveal a small acces ory nerve proceeding from the front of the plexus and curving medially to join the main hrenic nerve usually at the level of the left subclavian vein within the thorax

The phrenic nerve and any accessory seen is crushed the patient characteristically eeling pain in the shoulder and the upward lift of the diaphragm The retractors are emoved the platysma approximated by a few interrupted 0000 catgut sutures and the skin losed with Michel clips which are removed three days after the operation



(a)



(b)

Fig 9·16

(a) Large left upper lobe cavity: exudative disease in left lower lobe

A left phrenic nerve interruption and pneumo-peritoneum was employed as preparation for upper thoracoplasty

(b) The same patient as illustrated in Fig 9 16 (a)

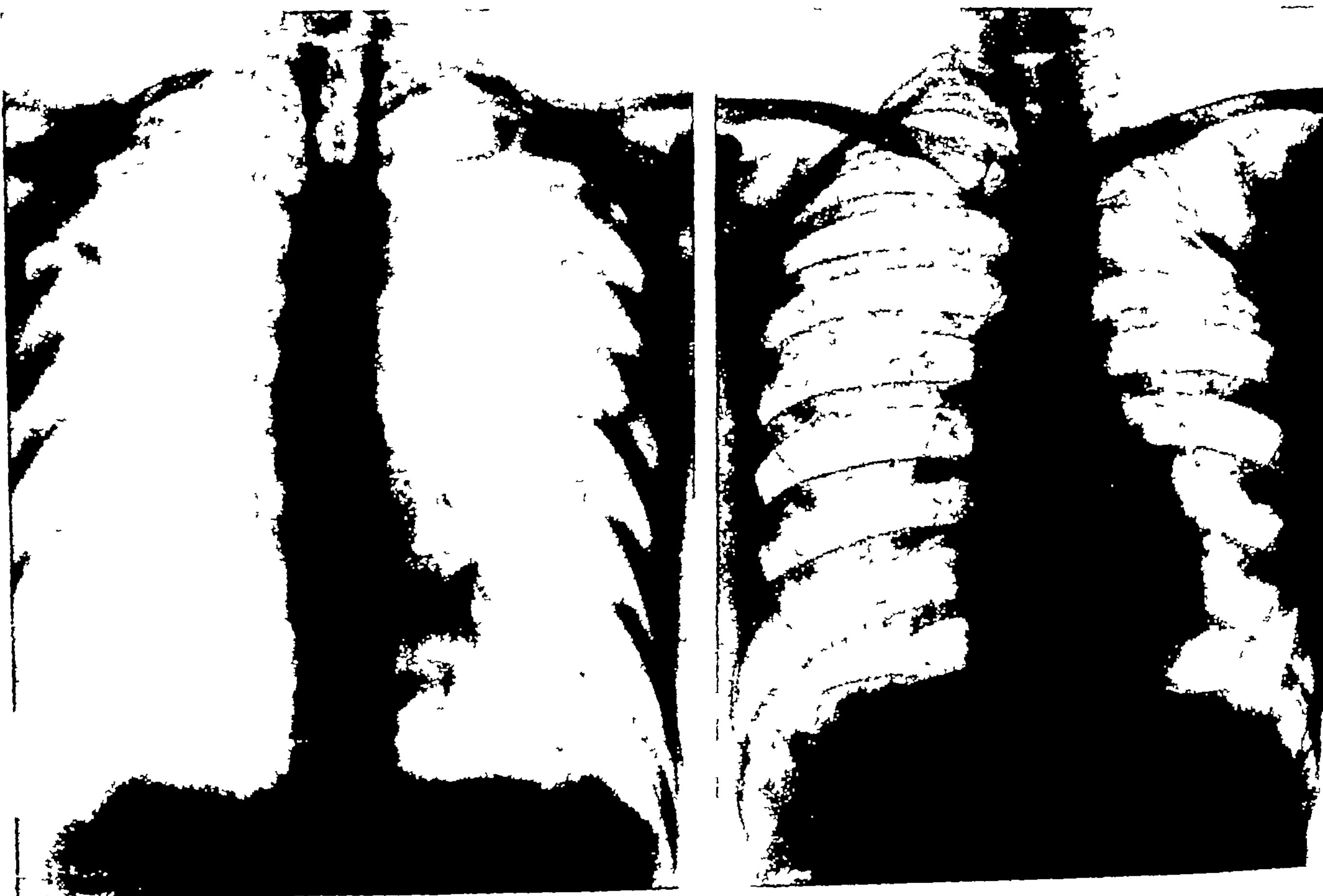
The cavity has closed and the pneumonic infiltration of the left lower lobe is much improved

The operation of phrenic avulsion has been abandoned when it was in extensive use occasional disasters followed the pulling out of the phrenic nerve These were due to intrathoracic bleeding In the unusual event of permanent phrenic nerve interruption being indicated the phrenic nerve should be divided in the neck and a very special search made for the accessory nerve

THORACOPLASTY

The ideal thoracoplasty provides a permanent selective collapse with minimal deformity and the preservation of as much functioning lung as possible This aim contrasts strongly with the achievements of the earliest ventures in thoracoplasty (Its chief indication is in the control of upper lobe cavities) Chemotherapy in tuberculosis is providing many patients in whom small segmental rather than larger resections can be employed Similarly many

patients adjudged suitable for thoracoplasty are being treated by far smaller but effective collapse operations than in the pre-streptomycin era The original Sauerbach paravertebral thoracoplasty in which small segments of many ribs were removed was slowly replaced by the Brauer subscapular thoracoplasty in which larger segments of the upper ribs were removed The next major change in the operation was the Scandinavian addition of apicolysis, performed in the extrapleural plane by Holst (1935) and the extrafascial one by Semb (1935) The Semb operation and its modifications rapidly became established



(a) (b)

Fig 9 17

(a) A supraclavicular cavity in a woman aged 30 shown by tomography
(b) The cavity has been closed by a one-stage small thoracoplasty involving resection of the first three ribs and very small sections of the fourth and fifth
The sputum has remained negative for seven years

as the best method of dealing with apical cavities in spite of many efforts to supplant it by less deforming procedures such as extra-pleural artificial pneumothorax These failed largely, especially when air was replaced by foreign material such as lucite or other modern plastic materials, because of the supervention of infection

At present, many patients with comparatively small upper lobe cavities who have been adequately treated by chemotherapy are submitted for thoracoplasty in spite of the increasing popularity of resection procedures The patients are very different surgical problems from those seen in the pre-streptomycin era because they do not have that extensive hard fibro-caseous disease affecting a wide area which required a thoracoplasty reaching down to the seventh or eighth rib in addition to a full apicolysis In providing permanent collapse for comparatively small upper lobe cavities the surgeon is reluctant to do an

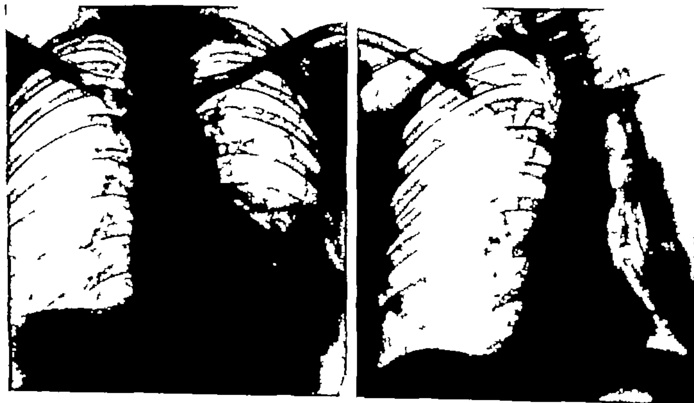
operation which produces the considerable deformity of the scoliosis and kyphosis is often followed by temporary but sometimes severe post-operative paradoxical chest wall movements and requires a two or three-stage intervention

Many interesting papers have been published describing successful operations providing a good upper collapse without gross chest deformity performed in one stage and followed by a post-operative period free from paradoxical movements Most of these operations can be placed under the heading of Osteoplastic Thoracoplasty (Holst (1952) Bjork (1954) Brock (1955) and Sellors (1955)) The same objects have been achieved by a simple but beautifully designed operation by Barclay (1955) which will be described later as the Glasgow type thoracoplasty and which I believe from personal experience provides an admirable permanent result and yet is technically simple to do

Extensive or total thoracoplasty

The extensive unilateral fibro-caseous disease with gross distortion of the mediastinum and extreme falling in of the over lying ribs which provided the earliest subjects for thoracoplasty in the brilliant pioneer work of Brauer Sauerbach Morriston Davies and Alexander are rarely seen today they represented survivors of advanced lung disease who by their natural resistance had lived long enough to win final relief by a nature assisting ten rib thoracoplasty

Earlier diagnosis bed rest antibiotic therapy now cure many patients before this stage and the aim in thoracoplasty is to cure or relieve by a partial upper operation There is still, however a place for extensive thoracoplasty in the treatment of a grossly disorganized



(a) (b)

FIG 9 18

(a) A woman aged 20 Two huge cavities in left lung.
(b) Two years after three-stage thoracoplasty

Sputum negative although such a patient present many indications for pneumonectomy thoracoplasty carries less risk and can be very successful.

lung, where the only alternative would be a pneumonectomy. (If bronchoscopy shows that the main stem bronchus is really damaged by tuberculous disease pneumonectomy, even in these days of streptomycin, carries a risk of bronchial fistula The empyema that results from such a catastrophe is difficult to close by the most thorough thoracoplasty In patients of that type, thoracoplasty can give excellent results (Fig 9 18))

Extensive thoracoplasty, however, is rarely in use and lung resection normally provides better results for widely destroyed, functionless lungs An extensive thoracoplasty is most commonly used today after pleuro-pneumonectomy especially if the pleural space so left becomes infected

Indications for thoracoplasty

When the lesion under consideration is one that demands permanent collapse, and the other lung is in a satisfactory condition with the patient suitable in other respects for major surgery, a thoracoplasty may be indicated The patients fall into five groups

(*i*) Extensive fibro-cavernous disease of the upper lobe with disease of the apical segment of the lower lobe
(*ii*) Truly apical cavities
(*iii*) Tuberculous bronchial diseases associated with a cavity which was " tension " in type before chemotherapy and anti-postural drainage
(*iv*) Patients over the age of 40 in whom resection is considered inadvisable largely on the age basis
(*v*) Patients with apical cavities who have had a previous pleural effusion

To diminish the size of the hemithorax after certain resections patients with some of these lesions are being treated by resection of the involved lung tissue

Thoracoplasty as an early measure will often save time, avoid or diminish the risk and provide a permanent collapse of a lobe that could never return to normal

Thoracoplasty in bilateral disease

The ideal patient for thoracoplasty has no disease in the contra-lateral lung, but were the selection of patients confined to this group, the number of patients treated by thoracoplasty would be small indeed and in over 50 per cent of those submitted to operation in this country there is disease in the " good " lung The closure of the cavity in the bad side will allow minimal or moderate infiltrations in the other lung to heal under treatment aid by antibiotic therapy In some patients the lung on the side opposite to the proposed thoracoplasty may require temporary artificial pneumothorax relaxation and if the pneumothorax is shallow the operation can be performed safely

Bilateral thoracoplasty has a small place in the treatment of suitable bilateral upper lobe cavities, it is a serious intervention and the results are not always satisfactory In an even smaller group the patient may be submitted to a thoracoplasty on one side and an extrapleural artificial pneumothorax on the other

Thoracoplasty operations

Thoracoplasty having been decided upon, the type of operation selected depends on the state of the patient and of the lesion to be treated There are many different types of operation in use throughout the world and the choice would seem to be bewildering, but in practice the principles governing the different operations are standard The usual operation used to be one in which large segments were removed from ribs one to five and

smaller ones from the sixth and seventh ribs Because of the dangers from and the common production of paradoxical chest wall movements this operation must be performed in two or three stages Such an extensive upper thoracoplasty is still required for some extensive lesions of the upper lobe associated quite often with disease of the apical segment of the lower lobe

The extent of the thoracoplasty This is regulated chiefly by the radiological extent of the disease it is usually necessary to resect one rib lower than the most inferior area of the disease and this is judged in relation to the posterior ends of the ribs In practice the actual resection often needs to proceed only to the sixth rib but the projecting seventh rib may impede the settling in of the scapula the angle of which tends to ride uncomfortably unless its posterior half is removed The extent of the resection is not always accurately prejudged by a study of the pre-operative X ray film because the extrafascial apicolysis may drop the level of the disease to a considerable degree Quite exceptionally for cavities sited above the clavicle a really small resection will suffice (see Fig 9 17) At the time of writing however there is an increasing tendency to combine an extrafascial apicolysis with an osteoplastic thoracoplasty a modified one as described on page 210 or by using a temporary extrafascial pneumothorax which keeps the apex down until the ribs have regenerated at a permanent lower level These operations are performed in one stage

Resection of the posterior ends of the ribs It is essential to resect the ribs to the level of the costo transverse joint and this means the rib should be divided through its neck or the neck and head be completely removed Unless the transverse processes are removed there seems to be little point in removing the neck and head of the rib and transversectomy has become increasingly unpopular because it adds to the risk of spinal scoliosis If however the ribs are not meticulously resected to the level of the transverse process the relaxation and mobilization of the posterior part of the thorax is incomplete and the collapse obtained inadequate as the regenerated ribs will become anchored to the jutting-out rib segments to mar a well-shaped thoracoplasty

The need for vertical as well as lateral relaxation Semb s extrafascial apicolysis When the ribs have been resected the lateral collapse obtained will be striking but the apex of the pleural dome is still held up above by strong muscular and fibrous bands since thoraco plasty aims to produce a selective collapse of the diseased area this superior fixation of the pleura interferes greatly with complete vertical relaxation The ideal thoracoplasty in this respect resembles the ideal artificial pneumothorax so that the apex of the lung falls well below the level of the clavicle to provide concentric relaxation of the upper lobe When a pneumothorax is ineffective for upper lobe lesions because of apical and mediastinal adhesions not divisible at thoracoscopy the substituted thoracoplasty may also fail if the same tension bands persist under the resected ribs To overcome this deficiency Semb (1935) introduced his extrafascial apicolysis to supplement the thoracoplasty The first attempt to correct this defect in upper thoracoplasty by performing an extrapleural apicolysis in the plane of the endothoracic fascia had been made by Holst (1935) but re-expansion of the lung is more likely after this operation and the more effective extra fascial apicolysis of Semb has largely replaced it The free use of Semb s procedure has led to the closure of upper lobe cavities in about 85 per cent of instances

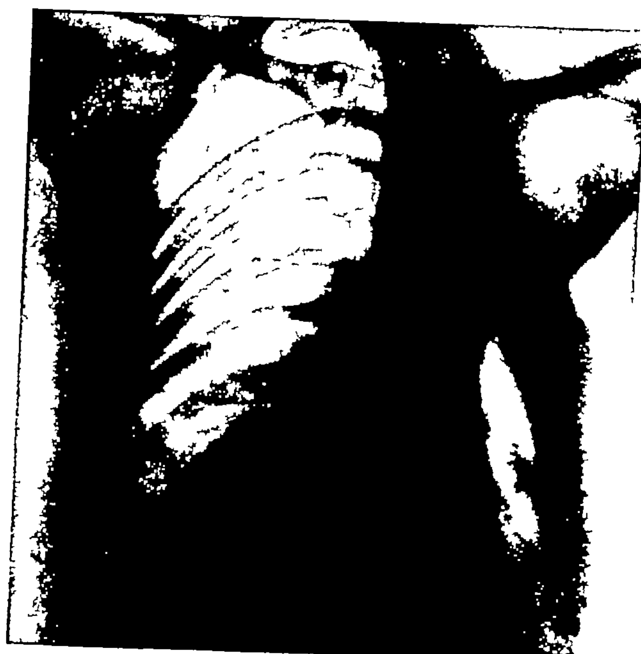
The production of minimal deformity Deformity will not be obvious if good physio therapy is available from the outset even with a ten rib thoracoplasty (now rarely per formed) the deformity will not be noticed when the patient is clothed Naturally the shape of the chest is altered and there is always anterior flattening but the greatest deformity is caused by spinal scoliosis and this can be minimized The correct posture after the



(a)



(b)



(c)

FIG 9 19

(a) A woman aged 35 A pneumo-peritoneum has failed to influence a left upper lobe cavity There is also disease below the right clavicle A left upper thoracoplasty was decided upon

(b) An upper thoracoplasty with apicolysis has closed the large upper lobe cavity But a year later there is a considerable cavity of the right upper lobe the vital capacity was only 800 c c and an extrapleural pneumothorax was considered to be the only possible treatment as artificial pneumothorax could not be established

(c) Six months after right extrapleural pneumothorax The cavity is closed and the sputum is negative 5 years later

operation requires constant attention most readily achieved by the patient's use of a mirror at the end of the bed and by the careful re-education of arm neck and spinal muscles by the physiotherapist



FIG 9·20 —The use of the mirror after thoracoplasty to prevent the development of scoliosis.

The operation of thoracoplasty

Pre-operative treatment General hygiene rest and chemotherapy are invaluable in the pre-operative phase and are associated with the usual dietetic fluid, electrolyte and blood restoration features common to any major thoracic operation The value of streptomycin given pre-operatively requires consideration Its rigorous exclusion as a preparatory treatment would prevent many patients from reaching the stage at which thoracoplasty could be used but at one time in thoracoplasty patients with chronic disease streptomycin was not often used In the carefully controlled Medical Research Council experiment (1951) its pre-operative use was not really effective but as a weapon against post-operative complications such as re-activations, new infiltration and wound infection its value was undeniable The position has however changed notably up to 1951 streptomycin and drugs were not used for anything like the length of time now in common use the aim today is to render patients sputum negative before thoracoplasty although this counsel of perfection is not always attained

Anaesthesia (*a*) *Local anaesthesia* Local anaesthesia is popular in some clinics the advantages over general anaesthesia being the decrease in blood loss and surgical trauma the persistence of a cough reflex the maintenance of quiet regular respiration and the avoidance of a lung irritant or of deep narcosis which may delay the return of conscious coughing when the patient is back in bed The early post-operative co-operation of the patient not only eases the post-operative nursing care but helps in the prevention of atelectasis or dissemination of the disease In the pre-operative phase the advantages of local anaesthesia are explained to the patient and with adequate premedication (omnopon and scopolamine) his co-operation in the theatre is usually good. The local regional anaesthesia should be produced by an anaesthetist skilled in this work and it is unwise for the surgeon to be responsible for this part of the operation it is in itself a tiring and lengthy operation requiring a most meticulous technique moreover in occasional patients

who become unco-operative and frightened during the operation the anaesthetist may be required to provide supplementary anaesthesia

For the safe and easy performance of an upper thoracoplasty with apicolysis the brachial plexus, the upper five or six intercostal nerves and the line of the skin and muscle incisions must be blocked the nerve block may be intercostal or paravertebral for the brachial plexus and the intercostal nerves a solution of 1 in 400 procaine with 1 in 1,000 amethocaine is used, amounts up to 50–70 c c being a safe total dose The skin and muscles are infiltrated with a weaker solution of 1 in 400 procaine with 1 3,000 amethocaine, a total amount of up to 200 c c being employed Adrenalin three minims of a 1 in 1,000 solution are added to each of the flasks containing the procaine solution to help haemostasis (Joan Millar, 1948)

At a second or third stage the brachial plexus block is not necessary, otherwise the same type of nerve block and infiltration is used

Complications of local anaesthesia The commonest complications are restlessness and bouts of coughing, if the latter is troublesome every inducement should be made to persuade the patient to cough up irritating pus or mucus, if the restlessness is severe the safest supplementary anaesthesia is often the administration of pentothal and a relaxant combined with intratracheal nitrous oxide and oxygen

A rare complication of local anaesthesia may be the development of severe convulsions, due to overdosage probably of amethocaine, if the amounts listed above are not exceeded they should not occur Their treatment is by immediate incision along the injected line to allow the fluid to escape and be mopped out with warm saline pads and the administration of intravenous pentothal During the injection of the local procaine into the intercostal spaces a small pneumothorax may be induced inadvertently The prompt recognition and treatment of this by aspiration of the air is necessary

(*b*) *General anaesthesia* This is satisfactory for many thoracoplasty operations and is used in nervous patients or those with skin infections or sinuses that may be complications of a pyo-pneumothorax for which thoracoplasty is to be undertaken Especially careful pre-operative drainage and post-operative bronchoscopic suction is required, when general anaesthesia is used for patients with much sputum

The induction is by pentothal and a relaxant followed by the passage of an intratracheal tube through which small amounts of nitrous oxide are given with large volumes of oxygen, a carbon dioxide absorber is connected to the circuit This combination is far superior to the use of ether or cyclopropane as adequate muscular relaxation is obtained in a fully ventilated and oxygenated patient The anaesthesia is maintained at a light level In middle-aged patients there has often been damage to both lungs and the risk of carbon dioxide retention is especially severe

The position on the table An exact lateral position with no twisting of the spine is essential for efficient operating A small pad is placed underneath the axilla and the chest piece of the table and the pelvic and buttocks props must be snugly in position to prevent any change of position while the scapula is being retracted, the underneath arm must be pulled well through beneath the patient so that the tendency to fall towards a prone position will be discouraged

The incision. *First stage* For this stage a large peri-scapular incision is used in this country, it commences high up at the highest point of the transverse sweep of the trapezius muscle, as this slopes from the neck to the scapula, unless this muscle is divided really high, scapular retraction is inadequate and unnecessarily strong and traumatizing The skin incision begins 1½ inches (4 cm) lateral to the spinous process and runs

parallel to the scapula until it turns forward 1½ inches below the angle of the scapula to reach the mid axillary line * The justification for this large incision is the good access it provides for the later stages of the operation and because it greatly eases the difficulty of scapular retraction The infrascapular muscles are then divided the approach to them is made through the area of the auscultatory triangle which is opened down to the loose areolar tissue overlying the ribs in this area When this space has been opened the assistant slides one finger beneath the overlying trapezius and rhomboid muscles on his side the surgeon doing the same on the other side of the wound the muscles held tautly upwards are divided by the diathermy cutting knife cut vessels being picked up in artery forceps

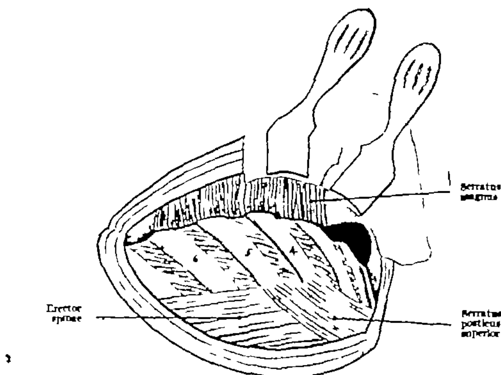


FIG 9-1 —Drawing of exposed ribs. But before division of the serratus magnus.

as the incision proceeds When the division of the muscle has proceeded nearly up to the neck the erector spinae muscle is seen clearly beneath

In the same incision the latissimus dorsi and the serratus anterior muscles are divided anteriorly This muscle carries large blood vessels on its surface which can be picked up on each side with forceps before the diathermy knife proceeds with their section

Haemostasis is secured by ligating the large vessels and applying the diathermy point to the others The scapula is held in a large moist saline pad and lifted well off the chest wall by the use of a scapula retractor, the loose areolar tissue binding it to the chest wall is divided by the scalpel until the digitations of the serratus anterior muscles are seen passing from the ribs to the scapula The serratus anterior muscle is then cut as close to the chest wall as possible by the diathermy knife this dissection should start at the upper border of the second digitation of the muscle this is the largest digitation and is separated from the first one by a small gap into which a finger can be inserted and hooked beneath the muscle band The first five digitations are severed and in the course of this the long

* The incision through the muscles may be made much closer to the spinous process so that an aponeurotic layer only is divided The musculo plastic incision described by Brock in 1946

thoracic artery and vein will be secured and divided as high up as possible The first digitation should be cut through slowly and carefully by long lobectomy scissors with the brachial plexus and axillary vessels kept well in view as they lie on its anterior surface, when this band has been freely divided the neuro-vascular bundle is seen lying above the first rib in the axilla

The serratus posticus superior muscle is partially resected from the chest wall to expose clearly the posterior thirds of the upper four ribs

The resection of the ribs Counting from above downwards the third rib is identified and its periosteum incised from the edge of the erector spinae muscle up to the costal cartilage by the diathermy knife The periosteal cuff is then elevated along the upper border first by Tudor Edwards's curved rib raspatory, the greatest care being taken to clear the upper edge clearly and fully with the instrument working from behind forwards, the lower edge is then cleared by working in the opposite direction, the final sub-periosteal clearance being effected by the use of Doyen's raspatory The outer edge of the erector spinae muscle is then divided with the diathermy point and the muscle fully retracted posteriorly by the use of two posterior end retractors The superior and inferior surface of the posterior ends of the ribs are then carefully cleared of their muscles, including slips from the erector spinae and the pleura and periosteum in front of the neck of the rib meticulously pushed away from the bone in the costo-vertebral gutter this is important as the pleura is easily damaged in this area The rib is then divided through its neck after the costo-transverse articulation has been opened, this may be done by Price Thomas's method of using the tips of his posterior end-rib shears to cut through the articulation and then sliding them down to cut the neck of the rib, an alternative method is to divide the rib in front of the articulation The small posterior ends are then grasped in special bone-holding forceps, the costo-transverse articulation being opened with Semb's disarticulating instrument and the neck and head of the rib removed by the use of posterior end punch forceps or rongeurs The front of the rib is then divided at the costo-chondral junction

Some surgeons prefer to resect only half the third rib at this first stage to decrease the risks of paradoxical breathing which is common after a first stage in which the whole of the first three ribs are resected

When the third rib has been resected a gauze swab is placed in its bed to check oozing of blood and to apply some firm pressure to the mobile lung and pleura

The second rib is then resected It lies far more horizontally than the third and after its periosteum has been divided its under surface is rapidly cleared by the use of Price Thomas's broad flat periosteal elevator, the whole of the under surface should be cleared before the upper edge is cleared, for after this has been done the underlying pleura is well away from the rib and the upper surface is easily freed of its periosteum and attached muscle The rib is resected from its transverse process to its costal cartilage

The resection of the first rib is conducted under full vision if the scapula has been fully mobilized off the chest wall and the serratus anterior (first digitation) has been divided As in the case of the second rib the under surface is cleared first to the neck of the rib across which the first thoracic nerve is seen joining the seventh cervical nerve, this cord is clearly seen and avoided The periosteum of the upper surface of the rib is pushed off the bone with Price Thomas's long curved periosteal elevator the scalenus anticus may be cleared from the bone at this stage or divided later by sharp dissection after the posterior end of the rib has been divided and held downwards in bone-holding forceps the anterior section of the rib should be at the costal cartilage junction The subclavian vessels are protected with a finger of one hand while the periosteum in their vicinity is being cleared

The extrafascial apicolysis The essential feature of Semb s operation is the section of all muscular slips and tendinous bands that pass down from the neck and thoracic wall to the fascia overlying the apex of the pleura. It is not a pneumolysis carried out in the extrapleural plane as is done in the operation of extrapleural artificial pneumothorax the extrafascial mobilization allows the upper part of the lung to be relaxed vertically as well as laterally The associated section of the periosteal envelopes posteriorly is followed by regeneration of the resected ribs in a position lower than their normal site and thus helps in providing a permanent decrease in size of the artificially created Semb s space

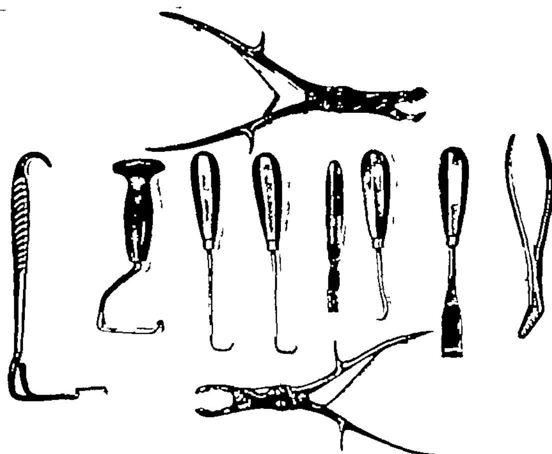


Fig 9·2* —Instruments used in thoracoplasty

Price Thomas angled rib shears.
Scapula retractors (2) | Director spinae retractors (2). | Farabeuf's raspatory | Small curved raspatory | Long curved raspatory | Bone-holding forceps
Rongeurs for removal of back ends of rib.

The fibrous envelope of the brachial plexus is freely incised and the lowest cord is gently retracted upwards by a small gauze swab held in a long slightly curved artery forceps This discloses a space between the nerve plexus and the subclavian artery in which lies a well-defined slip of muscle and tendinous tissue passing from the scalene muscles in the neck to Sibson s fascia (the *supra pleural membrane*) *a pair of curved forceps is passed beneath* this bundle which is then divided At once the subclavian artery in its thoracic portion is clearly exposed between it and the subclavian vein further forward a similar musculo tendinous band is seen and after being carefully isolated and cleared this too is divided The dome of the pleura with its overlying cap of fascial and extrapleural areolar tissue is depressed downwards by blunt pledglet dissection and the subclavian artery is thoroughly

cleared of its fascial investment, the internal mammary artery is seen passing downwards and forwards from its parent vessel and the line of dissection proceeds along the course of this vessel in the extrapleural plane

The intercostal muscle bundle, vessels and periosteum of the first three ribs are then isolated posteriorly and divided with appropriate ligatures on the sectioned vessels The pleural dome is then peeled downwards, still in the extrafascial plane so that the front of the vertebral column is clearly exposed the dissection in this area may be complicated by the presence of enlarged lymphatic vessels and of dense posterior fixation of the lung and pleura, the dissection here may involve the use of the scalpel which is kept close to the ligaments in front of the vertebrae The oesophagus is seen and lateral to it lies a strong band of fibro-muscular tissue passing to the longus colli muscle and this is divided to relax the apex of the pleura in this particular recess On the right side the pleura should be mobilized to the level of the azygos vein and on the left to the arch of the aorta so that the mobilized apex of the lung lies well below the level of the still unsectioned fourth rib In the large space so created a full view of the mediastinal structures is obtained * The incision is closed in two muscular and one skin layers with interrupted sutures of fine silk or 90 linen thread To prevent the apex of the mobilized lung from returning to its former site before the ribs regenerate the space may be filled with air for some weeks The wound is not drained

Operative complications. Accidental opening of the pleura may occur during the resection of the ribs or the apicolysis The tears are difficult to suture until the surrounding area has been well mobilized If the tissues are not free enough to enable sutures to be passed without tension, the opening should be closed temporarily by a moist pack, the use of adjacent muscle tissue such as an intercostal bundle is of value The intrapleural air must be aspirated at the close of the operation The thoroughness of this should be checked by observing the appearances noted on an immediate post-operative radiograph

Quite exceptionally during the course of an extrafascial apicolysis a chronic cavity with densely adherent walls may be opened, if the mobilization is thoroughly completed the cavity may then be sutured with unabsorbable stitches with satisfactory results (Price Thomas) The alternative is to proceed at once with a resection operation after the pleural cavity has been opened widely

Injury to the thoracic duct during the apicolysis may be detected during the operation, the injured duct should then be secured and ligated deliberately If the wounding of the duct is not seen at this time, the wound may fill up with chyle during the post-operative period

Minor leaks may become self-sealed, but if there is a lateral tear of the duct the outpouring of chyle may become serious at the second stage of the thoracoplasty, which will be done earlier than planned originally, the duct will be sought and tied The tear usually takes place on the left side near the subclavian vein It is a rare complication

The two commonest structures to be damaged either temporarily or permanently are the sympathetic nerve chain and the phrenic nerve Trauma to the former is shown by a Horner's syndrome on the affected side associated with increased warmth of the hand, while the phrenic nerve injury is detected by noting a raised immobile diaphragm in the first post-operative radiograph Tingling down the distribution of the ulnar nerve for a few days is not uncommon if the retraction of the lowest part of the brachial plexus during the apicolysis has been heavy or prolonged

* A very full description, with excellent illustrations, of extrafascial apicolysis has been given by Price Thomas (1950)

The subsequent stages In the absence of complications the second stage of the operation is performed 10–14 days later In the standard upper partial thoracoplasty large segments of the fourth and fifth ribs (14–16 cm of the fourth and 15–17 cm of the fifth) are resected much smaller lengths of the sixth and seventh ribs are resected 10–12 cm and 6–8 cm respectively to allow the scapula to bed in well Extensive resection of the fourth and fifth ribs may produce paradoxical chest wall movements and it is often wise to resect these two ribs alone at the second stage and in certain patients with truly apical cavities the resection may stop at that

The scapula with such a limited resection fails to help in maintaining the collapse and various devices have been used to overcome this The lower half of the scapula may be resected or the angle of the scapula embedded anterior to the sixth and seventh ribs after an extrapleural strip has been performed to fashion a bed for it This latter manœuvre inevitably interferes with the movements of the arm and neither has gained wide support

Post-operative care The post-operative course depends largely on the type of lesion and the general condition of the patient bilateral disease depressed pulmonary function and a badly expanding lower chest wall may cause considerable post-operative difficulties In this respect an easy convalescence can usually be predicted for the good chronic in which operation is being performed for an upper lobe cavity without serious disease elsewhere whereas the opposite holds when thoracoplasty is being performed on a bad risk slipping chronic with slight pyrexia a high blood sedimentation rate and extensive disease with poor pulmonary functional reserve These patients tend to develop atelectasis of the lower lobe which may require bronchoscopic aspiration

Immediate post-operative treatment In spite of theoretical disadvantages morphine or omnopon relieves the considerable pain which inhibits coughing and breathing more than the depressant effect of the drug on the respiratory centre The relief of pain and the encouragement of efficient expectoration of bronchial secretions are essential measures in the prevention of collapse of the lower lobe The wound area should be firmly strapped but encasing strapping or bandages that impede the movement of the lower chest are not allowed Paradoxical movements of the chest in which the operated side moves in an opposite direction to that of the sound hemithorax during inspiration and expiration may cause cyanosis as air passes from one lung to the other with a rising tide of carbon dioxide for this reason the patient on return to the ward may need oxygen, preferably given in a tent If the paradoxical movement is severe the front part of the chest should be steadied by a sandbag Routine physiotherapeutic supervision encourages diaphragmatic breathing corrects posture and encourages early movements of the shoulder The patient's own active efforts are the best preventative of scoliosis

Vomiting may be a troublesome complication and is best avoided by a reasonable limitation of the fluid intake by mouth for the first 36 hours the fluid requirements are made up by the use of rectal salines or exceptionally by the intravenous route especially if vomiting has upset the fluid and electrolyte balances Vomiting is only seen in patients with paradoxical movements and is probably due to the effects of a raised carbon dioxide content in the blood

Major complications of thoracoplasty

Atelectasis Collapse of the lower lobe though often transient and without serious sequelae is a major complication its early detection and treatment have been described on page 88 If it persists secondary infection in the lobe may cause severe toxaemia associated with pyrexia malaise and loss of appetite even if serious secondary infection

does not follow, the lobe may fail to re-expand and this will require a far more extensive thoracoplasty to be carried out than was originally intended or require later a lung resection if bronchiectatic changes develop

Bleeding into Semb's space A rapid increase of the fluid in the space associated with obvious clinical and haematological signs of anaemia will indicate this complication, it is treated conservatively by accentuation of rest and quiet and by blood transfusion, the wound will rarely require re-exploration Occasionally the wound will bulge and to prevent the risks of its disruption the fluid should be aspirated and streptomycin or penicillin instilled into the space A specimen of the aspirated fluid is submitted for bacteriological examination, for the sudden increase in fluid in the space may be an indication of pyogenic or tuberculous infection, for which appropriate treatment is necessary If pyogenic infection does not respond to the appropriate antibiotic agent given parenterally and locally, the space is drained by a tube well away from the line of the main incision after such drainage the second stage of the operation should be performed as soon as possible if the patient's condition warrants it, as the bedding-in of the scapula after further rib resections will obliterate or limit the area of dead space

A chronic tuberculous infection of Semb's space is serious and before the days of streptomycin was usually a fatal complication, but the results of daily instillation of streptomycin have given us a weapon of great efficiency

The late development of sinuses is not uncommon and, though often associated with the discharge of suture material from a wound that has perhaps been re-opened for two further thoracoplastic resections, should also arouse the suspicion of a tuberculous infection and bacteriological examinations are always called for

Modifications of thoracoplasty

Many operations have been designed to replace the standard thoracoplasty just described, chiefly with the object of achieving better cosmetic results The extensive resection of large parts of the upper seven ribs inevitably causes deformity, however unnoticeable this may be when the patient is clothed, but scoliosis and a bad neck position will occur if the co-operation of the patient is not achieved by the physiotherapist, and the transverse processes have been removed It is well to remember that the extensive use of extrapleural artificial pneumothorax, just before the last war, was partly encouraged by the hope that extensive thoracoplasty would be avoided, but the results were unsatisfactory and the operation has largely lost its place in this country

The disastrous results that followed the old plombage operation in which paraffin wax was moulded into an artificially created space included ulceration of the paraffin pack into the cavity (with subsequent expectoration of the wax) and infection caused by the discharge of the material through the wound, these complications have not been repeated on such a scale after the use of the newer compressive agents such as polythene or lucite, but even these have the continued disadvantage that they are foreign material bodies It is hard to believe that they are as efficient in their effects as the permanent collapse and downwards displacement of the apex of the lung produced by Semb's operation, in which regenerated and shortened ribs take up a permanent position at an ideal level and produce a lasting selective relaxation In some reports these materials have been responsible for infection and necrosis of the overlying ribs

In discussing these modifications it is difficult to write without prejudice, but the good results of the modern upper thoracoplasty combined with apicolysis with regard to sputum conversion and elimination are such that arguments in favour of cosmetic appearances

might not be accepted as valid unless the ultimate object the closure of the cavity is as good after the less destructive operation as after formal thoracoplasty O Brien (1950) writes trenchantly on the subject we go on our way embellishing techniques or substituting some new bizarre and often ridiculous measures which accomplish less than the ones they are intended to supplant

Some alternatives to extensive upper thoracoplasty

The varieties are almost innumerable in essence they consist of attempts to mobilize the apex of the pleura both vertically and laterally without the sacrifice of many rib segments the re-expansion of the upper lobe is prevented by suturing portions of stripped periosteum to newer sites or by swinging down ribs after resection of small posterior segments without sacrifice sometimes of the first rib and fixing them to lower ribs (Holst Bjork Brock, Sellors) These operations produce excellent results but are technically more difficult and probably not more effective than the Glasgow operation described below The filling up of the artificially created Semb s space by lucite balls has provided very good results in the hands of Cleland (1050) the good results reported in 1050 have been maintained but many surgeons continue to dislike the use of foreign body material in this space

In considering these procedures together with a combination of artificial pneumothorax O'Brien says when the extrapleural space is maintained by air these complications are almost the same as just described (i e those after artificial pneumothorax) but many surgeons are not satisfied with this debacle and fill the space with all sorts of foreign bodies The use of these procedures is haphazard unscientific inexact and inexcusable We have seen small cavities change in position but not in size under a 90 per cent collapse with pneumothorax or thoracoplasty How therefore can anybody without Divine Guidance know how much paraffin or how many lucite balls will be necessary to cause cavity closure? Furthermore once they are put to the space they obscure the X ray examination and one cannot tell whether the cavities are closed or not

Modern methods of plombage

The orthodox objections to plombage that have been expressed may be lacking in fairness and a personal failure to achieve enthusiasm may be based on obstinate prejudice An uncompromising condemnation of paraffin plomage is based on observations made on patients treated by this method in different clinics throughout the world with disastrous results of which severe chronic wound infection and bronchial fistula were *the most* important It has no place in modern surgery Recent work presented by Lucas and Cleland presents a more favourable picture These surgeons presented good results after thoracoplasty from the point of view of sputum conversion but have expressed their dislike of the resultant deformity of the need for multiple staged operations and because of the high incidence of post-operative complications such as atelectasis of the lower lobe Cleland has had as good results from thoracoplasty with plombage using polymethyl methacrylate or polyethylene the former in the shape of hollow spheres the latter as solid balls as after the modern type of thoracoplasty with apicolysis as far as sputum rates are concerned the advantages of his operation in his hands have been the *retention of an* intact thoracic wall the necessity often for only one stage and a notable decrease in the post-operative complications especially those of paradoxical chest wall movements and atelectasis His paper based on 125 cases with 3 deaths (none attributable to the plombage itself) and with only 5 post-operative examples of atelectasis should be read carefully

there were 3 space infections (2 being staphylococcal and 1 tuberculous) and 5 instances of wound rupture the latter complication he believes is due to the collection of fluid under tension in the space and this is now prevented by aspirations

An important feature of his operation is a really thorough extrafascial dissection, the plombage being used to prevent loss of the advantages of such a thorough vertical and lateral relaxation of the upper lobe and its overlying parietal pleura, the extent of the rib resection is half of the third rib and most of the second, the periosteum of the first and lower ribs is stripped from the deep surfaces of those bones and the intercostal bundles are divided posteriorly and carried forward with the mobilized lung, the denuded ribs being left intact The results of this operation continue to be excellent

The Glasgow thoracoplasty

Attempts have been made to decrease the deformity of the classical thoracoplasty by limiting the extent of resection and preserving the first rib intact The technical difficulties of performing Semb's extrafascial apicolysis with an intact first rib are obvious, though

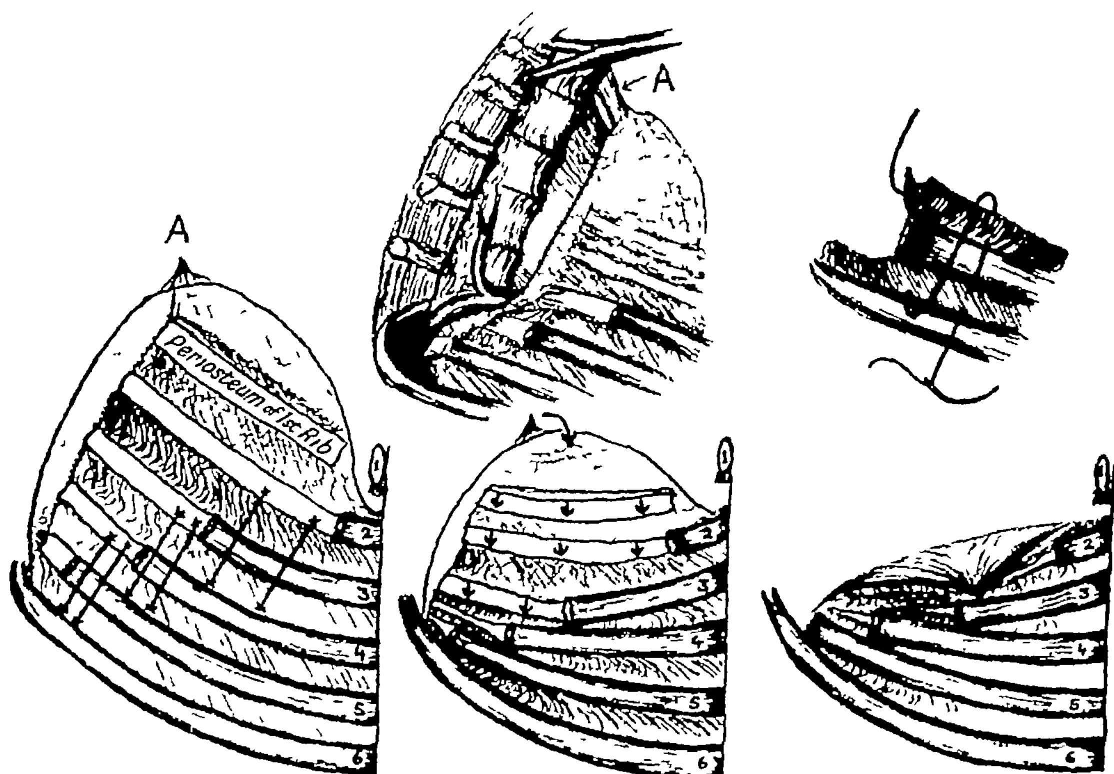


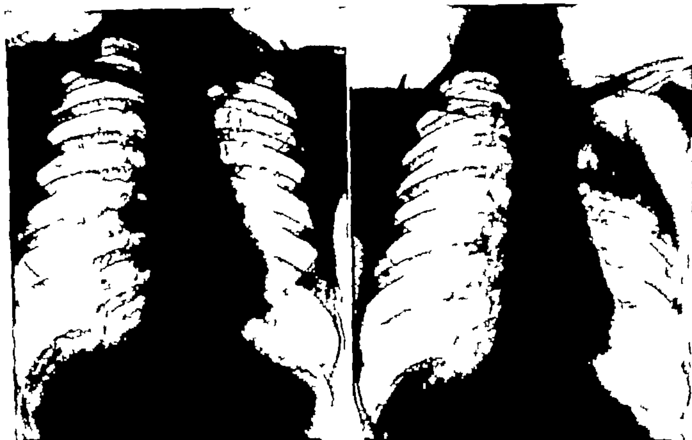
Fig 9 23 —The Glasgow type of thoracoplasty see text for details

mobilization in the extrapleural plane is easily obtained If the apex is displaced downwards by extrapleural dissection, re-expansion of the upper lobe takes place unless active steps are taken to prevent it, this tendency to re-expansion can be prevented by the operation of esteo-plastic thoracoplasty as described by the authors mentioned above A description is given here of an operation frequently practised in Glasgow I am much indebted to Mr Barclay and Mr Welsh for their great help in providing full details of

this operation I have adopted the operation with enthusiasm and the early results have been gratifying

The aims of the operation are a one-stage five rib thoracoplasty with stabilization of the chest wall in the early post-operative period The diseased apex is fixed by stitching it in an outward direction thus preventing the lung from creeping up in the paravertebral gutter A good cosmetic result is obtained by conserving the anterior ends of ribs two and three

Technique of the operation The incision is J shaped with its vertical limb situated just lateral to the spinous processes of the vertebrae cutting the common tendinous sheet



(a) (b)

FIG 9 24

(a) Cavity in left upper lobe
(b) Four months after Glasgow thoracoplasty
(Operation by Mr Barclay)

of trapezius and rhomboids and continuing in an outward direction across the latissimus dorsi Thus the function of the trapezius is preserved which improves the cosmetic result

Measured from the tip of the transverse processes one inch of rib five two inches of rib four about one third of rib three and not more than half of rib two and the whole of rib one are removed The removal of the first rib is an essential step to allow the correct plane for the extrafascial strip to be entered The conservation of large anterior segments of ribs two and three is also important if the deformity of subclavicular hollowing is to be avoided The posterior ends of the ribs are then removed by disarticulation at the costo-vertebral joint This move greatly facilitates the paravertebral part of the strip in cases where there is much fibrous reaction

Extrafascial strip The fibrous covering of the subclavian artery is incised and cut in a backward direction to the point at which the costo-cervical trunk is given off The fascial bands passing between the lowest cord of the brachial plexus, the subclavian artery and vein are divided followed by the tendon of scalenus anticus Division of this last structure displays the origin of the internal mammary artery and the phrenic nerve which may pass either superficial or deep to the artery—a point which, if not recognized, may result in injury to the nerve The internal mammary artery is secured between ligatures and divided Anteriorly the periosteum of the first rib and first intercostal muscle are divided. Posteriorly the intercostal muscles are cut and then the neurovascular bundles are secured close to the vertebral column and divided This last move gives additional tissue for covering the mobilized apex

On the left side the extrafascial strip in continued downwards until the fascia has been dissected off the surface of the aorta after ligating the superior costal vein On the right side again after division of the superior costal vein the arch of the azygos vein is swept away with the lung In the case where there has been much fibrous reaction the sympathetic trunk is sacrificed below the level of T 1 In cases with minimal reaction a triangular sheet of fascia can then be identified passing from the lung to be attached along the vertebral column deep to the reflection of the pleura This sheet is carefully isolated and divided close to the vertebral column for in the case where there is little reaction it forms an essential covering for the mobilized apex Where the fibrous reaction is marked it is more difficult to identify this sheet as it has been involved in the inflammatory process and, in any case, its use is unnecessary

Fixation of ribs By overlapping and stitching together the intercostal bundles the cut ends of the ribs are thus fixed This is achieved by stitching the second to the third bundle, the third to the fourth and the fourth to the fifth Usually two stitches in each situation are sufficient to bring about the desired result and gives adequate fixation Fixation of the ribs in this manner stabilizes the chest and thus obviates any risk of paradoxical movement with its attendant dangers Indeed, it was in an attempt to overcome this distressing complication that the operation was devised in the first instance With the fixing of the ribs the apex of the lung is displaced in an outward direction and the insertion of a few supplementary stitches results in the diseased apex being fixed in its new lateral position from which it cannot re-expand Thus we have a stable thorax and the new apex of the lung is covered by mediastinal pleura

The management of a cavity accidentally opened during extrafascial apicolysis

Whether a cavity be opened during a primary apicolysis or during a "corrective" thoracoplasty, the lines of management laid down by Price Thomas offer the best chance of success apart from carrying out an immediate lobectomy or segmental resection This surgeon points out that apart from faulty technique, such as ill-applied swab or finger dissection, the cavity may be opened when the ulcerative processes have so spread that part of the cavity wall is formed by the periosteum of the vertebral bodies

If the disaster happens the cavity should be carefully mopped out and filled with gauze, the mobilization of the apex should then be completed, as any attempt to suture the torn cavity will fail unless all tension has been relieved, the mobilization in fact should be more extensive than that originally planned Thorough bedding-in of the scapula is achieved by increasing the extent of rib resection, possibly including the eighth rib If mobilization has been really thorough the cavity can be sutured after excision of the torn edges and the

suture line buried by further layers of invaginating stitches If this cannot be done adequately a lobectomy is indicated

EXTRAPLEURAL PNEUMOTHORAX

This procedure (Tuffier 1891) has declined in popularity in Great Britain since the immediate pre war era when a considerable wave of enthusiasm supported its adoption Apart from the risk of infection in the artificially created space the method has the defects of attempting to replace the need for a permanent collapse by a temporary measure previously justified on the assumption that conditions in the same lung or that of the other side made artificial pneumothorax impossible or thoracoplasty too dangerous Experience has shown that good results are only rare after an extrapleural pneumothorax has been abandoned because of the frequent re-appearance of a cavity temporarily closed by high pressure air fillings or that the collapse attained has proved to be permanent and irreversible This latter experience has led some surgeons (Reid, 1946) to employ the operation as a temporary measure preparatory in itself for a later permanent thoracoplasty As Rafferty (1944) says it possesses all the disadvantages of a permanent measure with none of the advantages

The few remaining indications for this attractive but disappointing operation would seem to be

(1) In an occasional patient with bilateral disease unfit for thoracoplasty and yet presenting insistent demands for cavity closure unobtainable by other means this group might include patients who have undergone a successful thoracoplasty on one side and have developed a cavity in the upper lobe of the other lung which cannot be controlled safely by other measures or those with bilateral disease with a pneumothorax on one side that controls the disease but in whom tuberculous cavitation is proceeding in the other lung when pneumothorax or thoracoplasty is inadvisable for different reasons

(2) As a preparatory measure when thoracoplasty will be used later to produce a permanent collapse

(3) In children in whom thoracoplasty would produce a grave scoliosis and where a pneumothorax is contra indicated or unobtainable The aim in this group will be to complete the operation by thoracoplasty as soon as growth has ended and the danger of adolescent post thoracoplasty scoliosis has passed

Complications of extrapleural pneumothorax

These are mainly (1) post-operative bleeding into the space this may be alarming on rare occasions endangering life but it is chiefly dangerous because of the added risk of (2) infection in the space Infection in the space may be either pyogenic or tuberculous and on theoretical grounds this can be checked or prevented by suitable antibiotics or chemotherapy The rate of infection is given variously as 15 or 37 per cent (3) Failure of the lung to re-expand after a reasonable period of re filling in the absence of infection and in the face of a closed cavity this complication need not be serious as the space could be obliterated safely with a small thoracoplasty or by the use of *plombage* (4) The rupture of the cavity into the extrapleural space this happens if a totally unsuitable case has been selected in which the cavity wall obtains a large part of its blood supply from the chest wall

The technique of the operation

In choosing a patient for this operation it is unwise to regard it as a slight procedure or in the nature of a minor operation, for the attempt to produce an extrapleural pneumothorax space of small dimensions will always be a failure Complete separation of the apex of the pleura on all sides, including a strip on the mediastinal surface to the aorta on the left side and below the azygos vein on the right, is required The post-operative re-fills of air must be able to compress the lung from above downwards as well as concentrically, and this extensive operation must certainly be classed as a major procedure carried out with all respects to the modern demands for anaesthesia, anti-shock and anti-infective therapy The anaesthesia of choice is local novocaine infiltration of the brachial plexus, the upper seven intercostal nerves and the muscular planes exactly as for upper thoracoplasty

A large segment of the fourth or fifth rib is resected with meticulous separation of the periosteum from the bone The periosteum is carefully incised along the whole length of the exposed rib bed and the divided edges are held up in curved artery forceps The muscular fibres deep to the periosteum are separated carefully to expose the areolar tissue of the endothoracic fascia , once this layer is exposed its cobweb nature is obvious and its blunt dissection with small pledglets on long artery forceps produces a characteristic creaking sound This space is developed above and below the line of incision in the periosteum, and when an adequate space has been created a small rib spreader is introduced , the extra-pleural space can then be developed rapidly by blunt dissection As soon as the apex of the parietal pleura is reached a good illuminated probe or spatula is brought into use The first rallying point is the intrathoracic portion of the subclavian artery, and there is usually a considerable amount of areolar tissue around this vessel as it lies in the mediastinum and the apex of the pleura will strip down readily , more medially the phrenic nerve will be seen lying on the superior vena cava on the right and the subclavian vein on the left Care must be taken in its vicinity as there are small veins here , exact haemostasis is essential at all stages , if one area is tending to ooze a dry gauze mop should be left there for several minutes while the work of blunt dissection proceeds in a drier easier area , small vessels on the chest wall are sealed off by touching with a diathermy point a long pair of forceps affixed to them Occasionally rather stout bands of fibro-areolar tissue passing to the pleura from the parietes require scissor division

When the pleura has been displaced down to the level of the eighth rib posteriorly and to below the azygos vein or to the level of the aorta on the mediastinal surface and to the lower border of the fourth rib anteriorly, the space should be packed for a few minutes with dry gauze swabs , when these are slowly removed any bleeding can be checked either by diathermy or by the use of fibrin-plasma solution When the space is dry the incision in the posterior wall of the periosteum is closed by a continuous suture (nylon or catgut), and the space made airtight , though theoretically difficult this is not so in practice, and a satisfactory seal is achieved The wound is then closed in layers

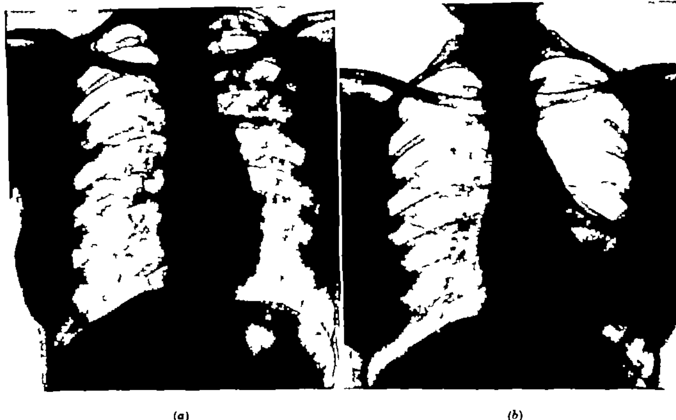
At the close of the operation the first re-fill is given through a needle placed usually in the third intercostal space anteriorly and enough air introduced to produce a pressure of + 15 cm of water

Post-operative management

Cough should be checked by morphia and the patient propped up as soon as reasonable , the routine observations on the colour, pulse rate and blood pressure will determine the presence or absence of bleeding and blood transfusion will be given as indicated

On the day after operation portable radiographs are taken A fluid level is seen usually due to the oozing of blood and serum into the space this sero-sanguinous fluid should be removed by the needle and a further re fill of air given to produce a pressure of between + 15 to + 20 cm of water

As soon as possible the positive pressure rate of the re fill should be diminished and it is a mistake to maintain high pressure re-fills too long once the separated pleura with the underlying lung has become covered with thick fibrinous tissue the re fill should approximate to the type associated with an intrapleural pneumothorax If the original selection of the patient for the operation has been based on the need to provide temporary relaxation



(a) (b)

Fig 9-23

(a) Bilateral disease in a woman aged 24

A large cavity in the left upper lobe with scattered areas of disease in the same lung complicated by lesion in the right upper lobe Perhaps the better line of treatment would have been a hazardous left thoracoplasty with right artificial pneumothorax, but a left extrapleural pneumothorax was adopted with satisfactory result

(b) Six months after a left extrapleural pneumothorax had closed the large left upper lobe cavity

The right artificial pneumothorax has been abandoned. Sputum negative

the extrapleural pneumothorax should be slowly abandoned after two years but in most patients the safest course to adopt is to achieve permanent collapse by a small thoracoplasty

In Great Britain this procedure is only rarely employed and few surgeons adopt it to any extent J E H Roberts an early enthusiast for the operation in 1937 and in 1938 had largely discarded it in his post war practice because of the poor results His opinion was based together with others on the failure of an operation that had a higher mortality rate than thoracoplasty (8 to 10 per cent) and is dogged by complications such as a rupture of the cavity and empyema formation into the space Perhaps the general impression that the operation is an unsatisfactory one is due to its application to hopeless risk patients and

to the high preponderance of bilateral disease in the series reported My own feeling after an initial enthusiasm for the operation is that it will not gain a permanent place in thoracic surgery

Its application has been sponsored in a more favourable light by Cutler (1951) who advocates a resuscitation of the method In a series of 129 operations on 121 patients (8 being bilateral interventions) there were 17 operative deaths (13 2 per cent), most of the deaths, however, were in the early part of the series before improved techniques and streptomycin were available Cutler now believes that the operative mortality can be regarded as less than 4 per cent, in spite of the fact that the operation is used in that group of patients who have serious disease not amenable to other collapse procedures because of the severity of the lesions Included in the patients selected were patients with bilateral disease, with active tuberculosis not responding to conventional methods and elderly subjects in the fifth and sixth decades Finally the operation has been used in young women, especially those who resist the idea of thoracoplasty

Unlike most supporters of the operation Cutler does not advise stripping the medial aspect of the lung from the mediastinum but advocates a most extensive extrapleural freeing elsewhere He has found streptokinase and streptodornase of value in the management of post-operative coagulation within the space

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CHAPTER 10

RESECTION OPERATIONS

Since incision and excision are used widely in surgery, it is not surprising that direct attacks upon the persistent reservoir of tubercle bacilli in the lung have been made, the first successful resection being performed in 1895 by Macewen of Glasgow (1906) Surgical resection of pulmonary tissue might appear hazardous from theoretical reasons The rupture of a cavity into an artificial pneumothorax, the development of a lung fistula, or the accidental opening of a cavity during thoracoplasty has often led to a disastrous tuberculous infection of the pleura or of the extrafascial or extrapleural space Deliberate resection of lung tissue is, however, quite different from the accidental opening of tuberculous tissue and can be executed without the spread of disease to the pleura or the extracostal tissues, though certain complications may follow The decision to employ resection remains a difficult one, but has become more clearcut since adequate antibiotic and chemotherapy has been used , fewer resections are being done than was the case five years ago

Some historical points

The first important report on a series of resections for tuberculosis made by Thornton and Adams (1942) showed a mortality rate of 45 per cent after pneumonectomy and 25 per cent after lobectomy , but these were gravely ill patients, unsuitable for thoracoplasty and denied the present-day advantages of individual hilum dissection technique and of streptomycin In 1943 Churchill and Klopstock presented an encouraging report on a small series of patients carefully selected, not as candidates for last hope salvage operation, but on physiological and psychological grounds, and there were no deaths This series represented the first serious challenge to thoracoplasty as the ideal operation for patients with fibro-cavernous and caseous disease Immediately after this many sub-total resections were done with too little attention paid to effects on disease in the other lung or the remaining lobe of the same side The acceptance of bad risk patients kept the mortality rate high

Overholt (1945) was able to report on a large series of 196 resections with 46 deaths (24 per cent) By the end of 1948 Sellors and Hickey had only 5 deaths after resection had been adopted deliberately in 55 patients with tuberculous lesions and in only one-third of these had streptomycin been used

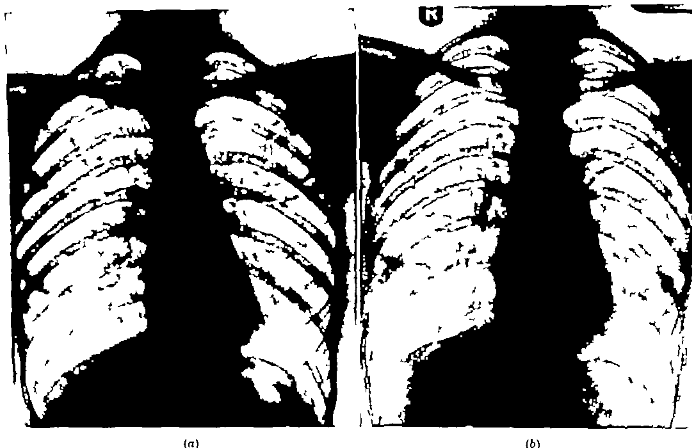
The application of Waksman's discovery of streptomycin and the replacement of the old tourniquet method of resection by meticulous hilar or lobar dissection led to a great decrease in mortality and post-operative morbidity figures and at the American meeting of Thoracic Surgeons in 1948, 475 resections, carried out with the help of streptomycin, were collected and gave a mortality rate of 9 per cent

With careful selection and better technique these figures were followed by reports from other clinics throughout the world, the biggest series published in Great Britain by Edwards (1951) and his colleagues giving a mortality rate of 2 5 per cent in over 200 resections

The same surgeon in 1955 reported that of 1,023 patients treated by resection, 20 died within three months of operation (1 95 per cent mortality rate) Dillwyn Thomas and his colleagues at Sully Hospital could say that in a five-year period up to June, 1953, 266 resections were done with an immediate mortality rate of 1 88 per cent Todd (1956) described 238 patients treated surgically by the staff of Midhurst Sanatorium (178 segmental

resections 58 lobectomies and 2 pneumonectomies) with no deaths in the immediate operative and post-operative period

In addition to a great fall in mortality rates the final results have been better and the complications have dropped this is largely due to the more continuous and thorough use of antibiotics and chemotherapy before surgery and after it Indeed most of the resections now are being performed in patients with negative sputum Nonetheless many patients are still having to have a salvage type of surgery these are usually patients in the older age group or those who have developed drug or streptomycin resistance as a result of sporadic inadequate treatment in the years before full prolonged courses were in use



(a) (b)

Fig 10-1

(a) Cavity in left upper lobe with dissemination of disease to other parts of both lungs
(b) Six months after full medical treatment It is this frequent result which has altered the whole surgical treatment of tuberculosis.

Indications for resection

At the moment of writing this problem must be perplexing to physicians and surgeons the results of rest with adequate drug and antibiotic therapy even in the most hopeless looking patients have ceased to startle us and certainly most patients being diagnosed today will never require surgery for especially in the early diagnosed case resolution is often the result The original major role of the surgeon in the past was in the treatment of cavities either by collapse or resection operations today apart from surgery for cavities still patent (and this is unusual) after 6-9 months treatment which may include streptomycin I N A H P A S and perhaps cortisone the main indication for surgery is for *the removal of permanently damaged tissue* (bronchiectasis) or of solid masses of caseation because of the fear that these may rupture into a bronchus and cause a spread of disease elsewhere

Resection and limited thoracoplasties indeed are being largely used as a method of providing insurance against future relapse or in those unusual cases in which drugs and antibiotics have failed

If a cavity persists, even though diminished in size, after 6–9 months of adequate medical treatment, surgery—usually segmental resection—is often practised (Fig 10 2) Conflicting reports appear in the literature as to the bacteriological state of the cavities which are usually associated with a negative sputum many investigations have reported that cultures from the walls of these cavities grow bacilli which are attenuated and of doubtful virulence On many occasions bacilli seen on microscopy in the walls of these cavities cannot be grown on culture The epithelialization of these " cysts " is rarely complete but many undoubtedly have been watched for years without troublesome sequelae Nonetheless many physicians and surgeons feel happier when this type of lesion has been excised Todd (1956) has produced evidence that resection of fibro-nodular disease diminishes the risk of relapse in patients without symptoms and who have been treated by chemotherapy and streptomycin and allows them an earlier return to an active life, *provided they continue with chemotherapy for a year post-operatively* Not everyone would agree with this plea for early surgery in these patients after such a comparatively short course of pre-operative chemotherapy but his patients were a selected group, mostly without symptoms at the time of detection of their disease My own feeling is that if tomograms show cavitation or solid foci at their previous site of areas of 2 cm in diameter after 6 months' adequate therapy excision should be considered and usually practised depending on the condition of the patient and the state of the lungs elsewhere

Although most of the resections being done today are segmental in nature the indications for lung or lobar resection will be considered later

Complications of resections

Before tuberculosis was treated by adequate doses of streptomycin used in combination with I N A H and P A S for long continuous periods we were prepared to accept the mortality and morbidity rates that followed resections, for the operations then were conducted as life-saving procedures carried out with determination to convert the sputum. Now that resections are being done largely with the object of preventing later relapse in a fit patient we must clearly be more critical of complications If we exclude the bad risk salvage type of patient (usually in the older age group) the mortality rate should not exceed 1–2 per cent

The immediate complications may be listed as

I	Difficulties with re-expansion of the remainder of the lung (temporary and readily corrected by efficient physiotherapy and bronchoscopy)	10 per cent
II	Broncho-pleural fistula (rare but serious)	3 " "
III	Empyema (rare and usually due to II)	2 " "
IV	Persistent air spaces (common but not usually serious if adequately treated)	7 " "
V	Post-operative bleeding requiring return to the theatre in the immediate post-operative period	1 " "

Broncho-pleural fistula used to develop and lead to empyema in patients whose active tuberculosis had not been controlled by adequate pre-operative therapy The complication is especially liable to occur when the bronchus is obviously involved by tuberculous disease It is therefore important that bronchoscopy should be carried out before any resection is done Such fistulae today are rare, they call for intervention usually as soon as they are detected The intervention usually means a re-opening of the wound and an inspection

of the bronchial stump which may be re-sutured or covered with available healthy tissue The residual space is then obliterated by a suitable thoracoplasty combined with adequate drainage to a water-sealed system If an empyema has developed this is drained and a thoracoplasty carried out



(a) (b)

Fig 10-2

(a) Tomogram of a cavity " leading off the apical segmental bronchus of the left upper lobe after 8 months of full drug and streptomycin therapy with bed rest. The segment was excised ; tubercle bacilli were present but could not be grown on culture

(b) Tomogram showing a thick walled cavity in the apical segment in a young man of 19 This cavity has persisted in spite of 7 months continuous chemotherapy An indication for segmental resection.

Far more common today however is the development of a persistent air space usually the result of small bronchiolar air leaks from the raw surfaces left after a segmental resection This complication is commonest after segmental resection If after 3–5 days of effective drainage by two intercostal catheters (one basal and one apical in position Fig 10-3) an air space is present on the radiograph the condition is regarded as a complication In most of the patients continued negative pressure drainage through a catheter will produce adequate lung re-expansion by the end of two weeks At that time further thoracotomy or the performance of a small thoracoplasty has been advocated by many surgeons If however the space is a small one and fluid free my own practice is rather a conservative one and after a long follow up of many of these I have little reason to regret it Frequent radiological examinations are necessary and if at any time the space is enlarged a small polythene tube is introduced and connected to a water-sealed drain I have *not seen* an empyema develop in any patient since the era of adequate chemotherapy became established a few of these air spaces have persisted for as long as 9 months before disappearing If fluid develops the problem is different and I believe a small thoracoplasty should be done Weisel (1957) and his colleagues have recently reported on 100 consecutive small resections and a third of them developed residual pleural air spaces They found that gradual resolution was the rule with infection of the space a rarity

Post-operative atelectasis of part or all of the remaining lung tissue is a serious complication calling for bronchoscopic aspiration if assisted coughing does not rapidly lead to re-aeration



FIG 10 3 —Photograph of a patient showing an apical and basal catheter connected to water sealed drainage bottles

The patient after resection of the apical segment of the right upper lobe is still in the theatre having been transferred from the table to the bed She has regained consciousness and oxygen is being administered while she is being transferred to the post operative ward

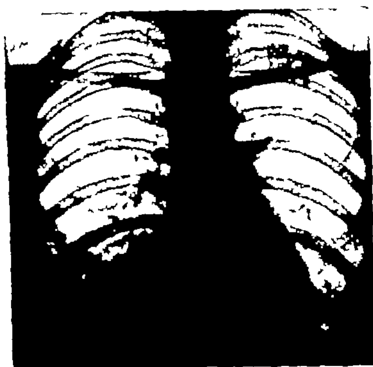
Lesions more suitable for resection than collapse measures

In selecting patients for thoracoplasty it has already been seen (Chapter 9) that each procedure has its own indication The saving of maximum function is always the aim and a segmental resection in this respect is superior to thoracoplasty

If a solitary lesion such as a cavity or a round caseous focus is to be treated surgically segmental resection is preferable to a thoracoplasty if the remainder of the lung fields are healthy (see Fig 10 2) It is over the question of major upper lobe disease that differences of opinion still exist as to the wisdom of performing resection or thoracoplasty If the lobe is largely collapsed and the remainder of the lung is healthy, resection often with a small thoracoplasty done at the same operation or later is probably wiser , if, however, the lower lobe on the same side is dubious then the tendency to do thoracoplasty will become more evident The chief indications for resection are now considered

(*a*) *Persistent cavity* Many physicians and surgeons believe that if a cavity persists after 6 months conventional treatment excision is indicated provided the rest of the lung fields permit this Especially so is this in the case of cavities in the apical segment of the lower lobe and the anterior segments of the upper lobes Cavities in the apical parts of the upper lobes may be treated by either resection or thoracoplasty with the general tendency to be in favour of resection if only the apical segment is involved by disease The problem of the smooth, ring-like cavity persisting in a patient with negative sputum has already

been discussed Keers Riddell and Reid (1960) studied 14 patients with persisting ring shadows at the site of previous cavities who had been sputum negative for periods of 4–14 months only two of these had had less than 6 months continuous chemotherapy immediately before operation From these patients ten resection specimens were available for study in nine of them there was evidence of tuberculous activity as assessed by combined bacteriological and pathological investigations Those who favour conservatism in the management of such open healed cavities might say that the chemotherapy had not been employed for a long enough period



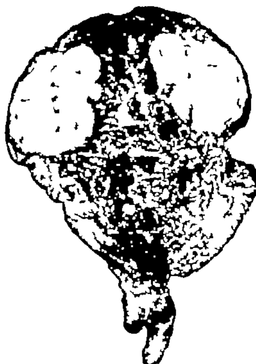


Fig 10-4 Fig 10-5

Fig 10-4 —Cavitation in left upper lobe "tuberculoma"

The patient, a young woman of 25, w radiographed t years before this as contact case a solid shadow wa then detect d she remained in good health. Control radiographs were taken at three-monthly inter als, and the ca ity noted in the solid mass seen bove was regarded as an indication for resection. Tubercle bacilli were recovered from this ca ity after resection.

Fig 10-5 —Resection specimen

(*b*) *The tuberculoma or massive nodular disease* is obviously incapable of being altered by pneumothorax or thoracoplasty This type of conglomerate tuberculous focus usually runs a benign course and may often be detected by routine radiology it can however break down suddenly and rapidly spread tuberculous infection throughout the bronchial tree Presenting as a mass on the radiograph it may be mistaken for a tumour innocent or malignant* it is usually treated best by thoracotomy and resection as it has an unpleasant habit of breaking down into a cavity Its removal should, if possible be local either by segmental resection or by resection-enucleation It presents as a massive encapsulated focus in which either caseation or cellular reaction many predominate and is often a completely blocked cavity

Tuberculomata may be multiple or one may be present elsewhere in a lung containing

* The diagnosis of a tuberculoma in a patient over the age of 40 is dangerous: round shadows over that age are often due to carcinoma and their surgical exploration should be urged

a cavity the practicability of removing this type of lesion locally adds a valuable weapon to the resection programme

(c) *Tuberculous bronchitis and destroyed functionless lungs.* These cannot be relaxed or compressed by phrenic nerve interruption, artificial pneumothorax or thoracoplasty



(a) (b)

FIG 10 6

(a) Consolidation of right upper lobe in male aged 40 years

Haemoptysis sputum positive General condition good with no pyrexia, but there had been three small haemoptyses Thoracotomy and right upper lobectomy were undertaken This tomograph shows cavities in consolidated area The shadow near the axilla is due to old lipiodol

(b) Radiograph taken one year after lobectomy the patient has now been at full work for 18 months

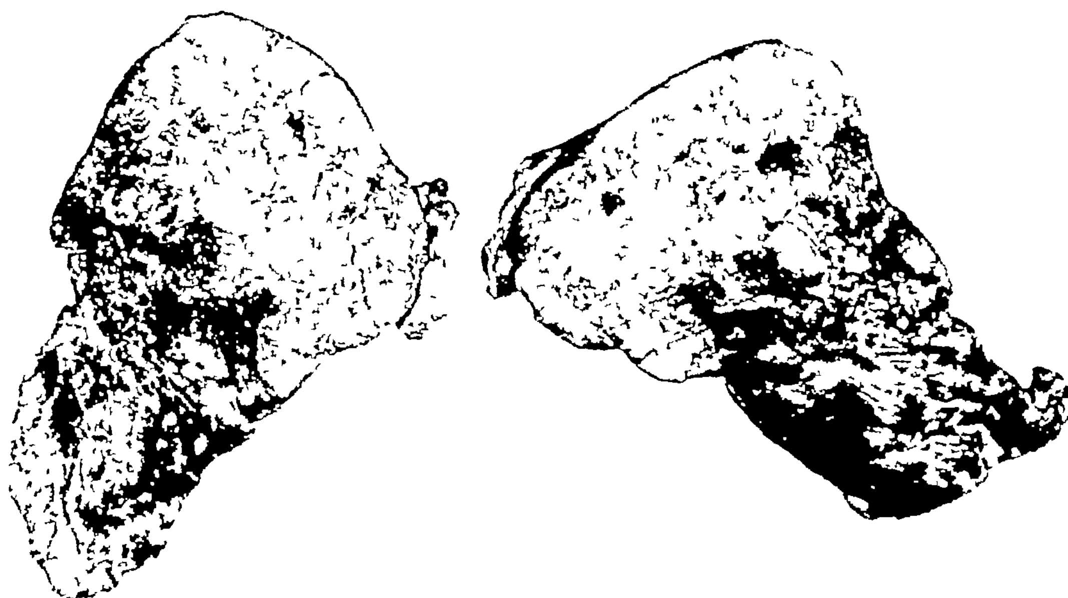


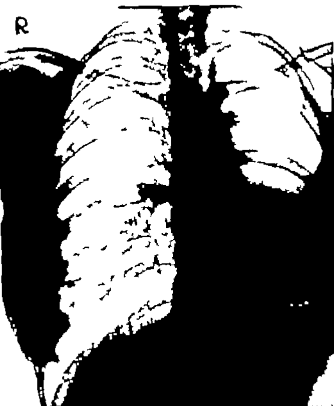
FIG 10·6 (c) —Solid caseous disease, right upper lobe
Treated by lobectomy



(a)

Fig 10-7

(a) Bronchiectasis shown by lipiodol bronchography of a long-standing example of pulmonary tuberculosis (six years) with persistently positive sputum.





(b) (c)

Fig 10-7

(b) After left pneumonectomy

(c) Conservative thoracoplasty with retention of first rib.

There is fluid in the extracostal space (Radiograph taken three days after five-rib thoracoplasty conserving the first rib.)

because the rigid, dilated bronchi and their surrounding solid parenchyma are uninfluenced by such measures

Tuberculous bronchiectasis is seen in its truest form when a stenosing tuberculous endobronchitis has caused pulmonary collapse with associated dilatation of the bronchi. The copious positive sputum, the shrinking of the overlying chest wall, the distortion of the mediastinum to the side of the disease, the bronchographic appearances and the demonstration of a tuberculous endobronchial lesion in the main stem bronchus provide a classical picture. No collapse measure can cure this condition and if the other lung is "good" the treatment is by pneumonectomy usually followed by a later thoracoplasty designed chiefly to prevent over-distension of the remaining lung, especially if this shows evidence of healed or quiescent tuberculous disease



Fig 10 8

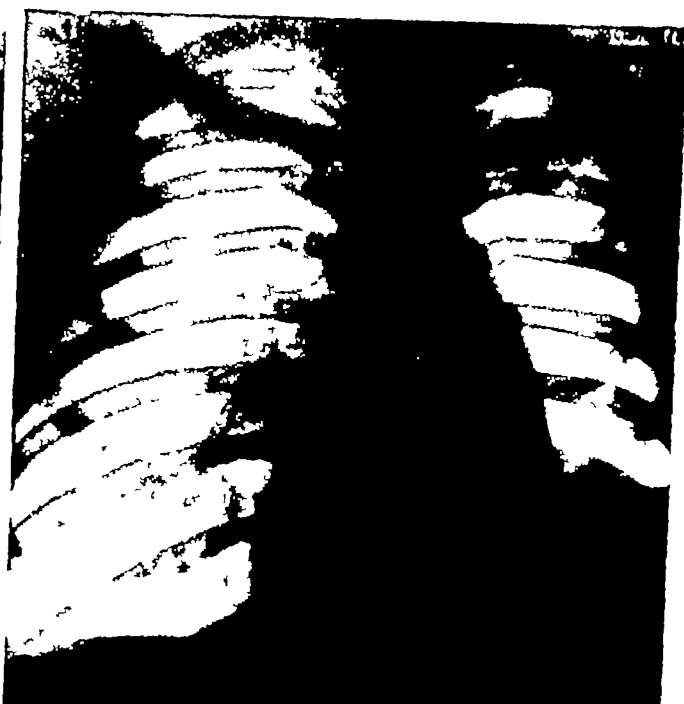


Fig 10 9

Fig 10 8 —Three large cavities in the right lung
An indication for pneumonectomy to be followed by a partial thoracoplasty

Fig 10 9 —Tuberculous pyo-pneumothorax associated with total atelectasis after artificial pneumothorax
An indication for pleuro-pneumonectomy

Not always will a tuberculous stenosis, or the presence of tuberculous granulation tissue, be seen in these patients. The lung may have become atelectatic during previous collapse therapy and, if re-expansion has not been obtained quickly, bronchiectasis will almost inevitably develop

Resection for tuberculous bronchiectasis not only rids the patient of the troublesome symptoms of constant cough and expectoration of a large area of sepsis that may terminate in severe toxaemia and even amyloid disease, but aims at stopping the spread of tuberculous disease to the other lung. The hazards of this operation on a chronically ill patient may appear great and the mortality rate high

The "destroyed lung" Extensive unilateral disease with extreme fibrosis or multiple cavities (Fig 10 8) or with one or more cavities in the upper lung and a completely atelectatic

lower lobe not only destroys most of the respiratory function on that side but is the source of copious sputum containing tubercle bacilli. Although thoracoplasty may leave the patient with bronchiectasis it still has a place and is free from the risk of leaving the patient with a bronchial fistula and an empyema.

(*d*) *Bronchiectasis with tuberculous empyema.* If the other lung is sound pneumonectomy is often indicated for patients with an associated tuberculous empyema. This complication used to be seen when artificial pneumothorax had been followed by atelectasis, fluid formation and bronchiectasis in an unexpandable lung. Pleuro pneumonectomy is the procedure adopted in dealing with this formidable problem, the parietal pleura being removed together with the lung (see p. 248)

(*e*) *The failed thoracoplasty.* If a well-executed thoracoplasty with apicolysis has failed to close an upper lobe cavity it is reasonable to presume that the lesion is one that will not heal by relaxation methods. This important group of failures represents about 15 per cent of all thoracoplasties. In retrospect these patients usually had large chronic cavities or were associated with atelectasis and perhaps represent the results of bad selection. Many of these failures are now being retrieved by resections carried out beneath the thoracoplasty and undoubtedly represent a strong indication for excisional surgery.

Lesions that may be suitable for resection or collapse methods or a combination of both

The indications for resection already discussed are generally acceptable. The main field for argument as to the place for excision is when this is advised as the primary method



FIG. 10.10. Radiograph after left upper lobectomy and a very conservative left upper thoracoplasty.

in the treatment of cavities. Here again opinions almost universally favour lobectomy or segmental resection for lower lobe cavities that have not closed after phrenic interruption

pneumo-peritoneum or pneumothorax used commonly as combined methods and when conditions elsewhere in the lung fields do not provide contra-indications to any form of major surgery

The real problem is in the treatment of upper lobe cavities where thoracoplasty or resection is not contra-indicated for any strong reason , both methods have a low operative mortality rate.

The psychological effect upon the patient when he knows that the disease has been actually extirpated is most valuable and supplements the physiological advantages of resection over extensive thoracoplasty The last-mentioned advantage will be great if the



FIG 10 11 —Collapsed upper lobe containing a chronic thick-walled cavity and bronchiectasis Lobectomy specimen

conservative segmental resections now being practised all over the world bear the test of time

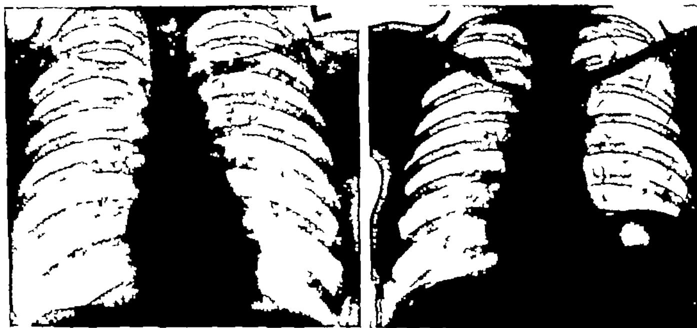
If however, upper lobe cavities are associated with doubtful *lower lobe* states, thoracoplasty is still probably the better operation unless the resection can be supplemented early by a thoracoplasty for the relaxation provided by the collapse measure often enables the *lower lobe to recover* An upper thoracoplasty in such circumstances, that is followed by healing of the lower lobe lesions, is infinitely preferable to total lung extirpation

The response of early tension cavities to bed rest is probably an important guide to the selection of the operative procedure *If a tension cavity enlarges under strict bed rest or* artificial pneumothorax it tends to do badly under a thoracoplasty and resection may well be indicated in such a patient

Resection is often required for the truly atelectatic upper lobe that contains or has contained a cavity for although thoracoplasty has been of value in the past in this type of disease its results have been erratic

The examination of resection specimens shows that many radiological appearances regarded as being due to fibrosis are in fact areas of segmental atelectasis

The types of patients mentioned above belong to a group in which resection is probably correct Considerable difficulty still exists in patients with upper lobe cavities associated with endobronchial tuberculosis These patients though totally unsuitable for pneumo thorax do well with thoracoplasty in 85 per cent of instances The immediate results of resection are excellent but relapses occur The patient illustrated in Fig 10 12 was a young married woman of excitable temperament she had an obvious cavity associated with the



(a) (b)

Fig 10-12

(a) Left upper lobe cavity with endobronchial disease in a young woman.
(b) Eight months after left upper lobectomy and left phrenic nerve paralysis

stigmata of endobronchial disease The physician in charge attempted a pneumothorax the upper lobe was in obvious danger of becoming atelectatic and the cavity was ballooning Thoracotomy was therefore done and the lobe resected the sputum became negative the day after operation *Six months later she was in perfect health* free from disease and with persistently negative sputum but 18 months later a positive sputum developed and the radiograph showed disease in the apex of the left lower lobe A small thoracoplasty was done and the sputum again became negative

Resection is undoubtedly becoming more popular in the treatment of upper lobe cavities but it is too early to assess the results and thoracoplasty has not lost its place in the case of chronic upper lobe cavities In spite of the danger of prophecy it is probably right to say that resection will be combined with a small upper thoracoplasty in many of these patients (Fig 10 10)

Resection for lower lobe cavities

Excisional surgery has removed many of the difficulties in the care of lower lobe cavitary disease, the treatment of which has been discussed in the previous chapter (p 187). If bed rest, a full course of antibiotics and chemotherapy fail to close the lesion, lobar or segmental resection is practised unless contra-indications are provided by the state of the lung tissue elsewhere Results of excisions have been satisfactory and this addition to treatment has largely removed the pre-war pessimism that coloured the management of lower lobe disease

Summary of the indications for resection

Listing the indications for any operation today in the treatment of tuberculosis is difficult It is easier to lay down the conditions for surgery in the advanced stages of any disease and pulmonary tuberculosis is no exception, certain indications being established while others are still speculative

The established indications

(1) Gross unilateral disease total bronchiectasis usually with broncho-stenosis and the destroyed lung if these states are combined with empyema the extirpation should be in the nature of a pleuro-pneumonectomy (Sarot, 1949)

(2) Lobar bronchiectasis associated with tuberculous sputum after adequate chemotherapy

(3) The nodular caseous mass, " tuberculoma ", or blocked cavity

(4) Cavities uncollapsed by good thoracoplasty , most persistent " ring " shadows

(5) Lower lobe cavities that do not close under the lesser measures of phrenic nerve interruption, pneumo-peritoneum with chemotherapy

(6) Most giant cavities and chronic multiple cavities in one lobe

The applicability of these indications to the individual must depend on the general state and the degree of tuberculous disease elsewhere in the lungs

The doubtful indications

(1) Upper lobe cavities with a considerable element of bronchial disease sufficient to cause atelectasis Although thoracoplasty may close these the results are doubtful in 15 per cent of them

(2) Upper lobe cavities without much surrounding parenchymal disease In this group upper thoracoplasty is probably the better treatment , its results are excellent with a 95 per cent sputum conversion rate , if it fails the 5 per cent group can be treated later by resection without any grave disadvantage to the patient

The extent of resection

As tuberculous disease often spreads across interlobar fissures lobectomy and segmental resection may involve cutting across tuberculous tissue, with possible resultant complications Ideally the resection should ablate the disease without transection of tuberculous tissue For this reason an extrapleural dissection is desirable when the diseased lung tissue is adherent to the parietal pleura, to avoid or lessen the risks of contaminating the pleural cavity when the lung in the presence of a total empyema is being resected by pleuro-pneumonectomy

The conservation of as much healthy lung tissue as possible is desirable and the

incidence of segmental resections rather than lobectomy has been rising steadily in recent years

Excisions of tuberculous tissue are not comparable to those required in cancer surgery and the natural tendency for this disease to heal when local and general conditions are placed on a satisfactory basis should not be overlooked especially under the satisfactory chemotherapeutic regime of today

Pneumonectomy or pleuro-pneumonectomy is required for extensive bronchiectasis *following broncho-stenosis* for destroyed lungs and for certain examples of tuberculous pyo pneumothorax associated with gross pulmonary disease involving both lobes It must be remembered that empyema and bronchial fistulae are not infrequent complications of these major resections thoracoplasty still has a place in the treatment of these grossly diseased lungs and often gives very satisfactory results if the resection of ribs is adequate

The indications for segmental resection

If segmental resections can remove safely the main tuberculous focus the physiological results are obviously better and the early experiences of Chamberlain and Klopstock (1950) Overholt (1950) and Edwards (1950) were encouraging In spite of the transgression of tuberculous tissue in these limited operations the post-operative incidence of broncho-pleural fistula and empyema has been small although persistent air spaces may be a cause of anxiety (page 221) If this operation is to be used there must be firm evidence that the patient has had or has the capacity of healing any small foci in the same or opposite lung this includes general and haematological evidence of good resistance and the availability of a series of films showing the natural trend of the disease in the previous months of treatment

The segments most amenable to resection are the apical ones of the lower lobes (these may require resection together with an upper lobectomy for cavitary disease because nowhere else is trans fissural spread so common as at the superior end of the great oblique fissure) and the apical and posterior (posterolateral) segments of the upper lobe

The technique of the resection must be meticulous and the principles are those that govern the procedure as adopted in the surgery of bronchiectasis (see pp 10 173) namely precise isolation of the arterial venous and bronchial channels clamps on the tissues that are to be left are avoided apposition of the raw surfaces of the adjacent segments to normal lung by a few sutures being done Since the resected segment is usually atelectatic the neighbouring lung tissue has already undergone inflating emphysema and the space is rapidly obliterated

Because it minimizes the sacrifice of healthy lung tissue segmental resection has a particular place in the treatment of bilateral tuberculosis of limited extent

A description of the anatomical approach to the various segments has been given in Chapter 1

Should thoracoplasty or phrenic paralysis with pneumo-peritoneum be employed *after resection operation or before?*

After resection of a lobe or lung there are two apparently claimant reasons for thoracoplasty (*a*) the thoracic cavity should be lessened in size to prevent over distension of the good lung and in the case of lobectomy of the remaining lobe especially if the latter shows any signs of tuberculous disease however quiescent it may be (*b*) if there is a residual pleural space either a total pneumothorax or a localized pneumothorax this carries a risk of infection The late slow development of an insidious empyema after total pneumonectomy is a well recognized condition

In most patients in whom the upper lobe has been resected the wisest course to adopt is a modified upper thoracoplasty in which the first rib may be left in place but in which the second third, fourth and fifth ribs are resected in one stage , this is sufficient to decrease the risk of over-inflation of the lower lobe , if the resected lobe is small and contracted thoracoplasty may be avoided

A lobectomy may be substituted for the second stage of a planned upper thoracoplasty since the results of upper thoracoplasty for certain cavities remain problematical until the apex of the pleura has been released, the first stage of a thoracoplasty is performed with Semb's mobilization procedure If the post-operative radiograph suggests that this vertical



FIG 10 13 —Thoracoplasty after left pleuro pneumonectomy for tuberculous empyema associated with destroyed lung

relaxation has not really influenced the size of the cavity, at the second stage after the fifth rib has been resected, the pleural cavity is opened and the upper lobe removed

Bickford and others (1951) have shown the good results that can be achieved in decreasing the size of the hemithorax after resections by phrenic nerve paralysis and pneumoperitoneum if the diaphragm can be kept well elevated for 8–12 weeks after the resection If it is maintained at an abnormally high level for this period it usually remains there permanently and the need for thoracoplasty may be avoided Klopstock (1956) has lessened intrapleural spaces by sewing down a large pedicled pleural flap, fashioned from the parietes, as a pleural dome [pleuroplasty]

Some technical considerations in resection for tuberculous bronchiectasis

The usual pre-operative measures include a long course of streptomycin and chemotherapy The anaesthetic problems are those for bronchiectasis in general the Thompson

blocker is useful for pneumonectomy patients to allow smooth anaesthesia by avoiding the blocking of the airway by sputum and to lessen the post-operative risk of spread of tuberculous disease to the sound side Occasionally bronchostenosis may be present almost up to the carina and then the blocker cannot be used careful post-operative bronchoscopic aspiration is indicated

During the course of lobectomy or pneumonectomy cutting into tuberculous tissue must be avoided as far as possible Where the lung is densely adherent to the parietal pleura the dissection is carried widely into the extrapleural plane This extrapleural dissection may be the cause of considerable blood loss and the transfusion requirements must be met promptly The dissection of vessels and bronchi is more difficult than in cases of bronchiectasis or carcinoma because of the obliterative effect of tuberculous disease on tissue planes and the production of dense fibrous reactions

The bronchus main or lobar is sectioned as close to the trachea or main stem bronchus as possible a long stump increases the risks of fistulous formation but a small fringe of bronchial tissue should be left in upper lobectomy to avoid the need for placing sutures in the rigid cartilaginous framework of the main bronchus For the reason given elsewhere (p 273) the open bronchus technique is used Technical and anatomical details concerning pneumonectomy lobectomy and segmental resection are given in Chapters 1 12 and 8

If the resection has been lobar or segmental the chest is drained by apical and basal catheters leading to water-sealed bottles (Fig 10 3) but it is closed without drainage after a total pneumonectomy the pressures being adjusted and left slightly positive at the close of the operation

The question of closing the space by thoracoplasty or by pneumo-peritoneum has been discussed The decision to avoid thoracoplasty has been based on humanitarian rather than scientific reasons but usually it should be advised after total pneumonectomy Such a post pneumonectomy thoracoplasty may be a limited one the first rib being spared and generous segments of the second third fourth, fifth six and seventh ribs being resected

Surgery in the treatment of the complications of the primary complex

The glandular enlargement that accompanies the primary focus may not always follow the expected benign course compression of segmental or lobar bronchi often leads to atelectasis (so-called epituberculosis') or in a truly major lymphadenopathy the whole bronchus or the trachea may be seriously occluded Before the obstruction becomes complete emphysema of a segment lobe or lung may be detected radiologically (see Fig 10 14) while in the case of tracheal compression severe stridor with grave respiratory embarrassment (Fig 10 15) may develop Not infrequently caseation of the glands may lead to perforation into an air passage with subsequent bronchiectatic destruction of the lobe or lung with dissemination of the tuberculous focus throughout the lungs

Because a significant number of patients usually children may develop serious complications from a primary infection the practice today is to treat these lesions seriously and prescribe full antibiotic and chemotherapy for them If the therapy is employed when the glandular part of the complex has become important the chemotherapeutic agents may not reach the bacilli within the glands and their compressive action may continue up to rupture or complete compression of the bronchus Under such circumstances the indications for surgery as first outlined by Dillwyn Thomas (1952) may have to be followed The essence of Thomas's advice is that if possible serious sequelae such as total lobar or lung collapse are likely thoracotomy enables a timely removal of the caseating glands to be

effected In my own service the chief indications for such interventions have been (*a*) for tracheal obstruction in infants with stridor and grave dyspnoea (*b*) for severe emphysema with tomographic evidence of main bronchus obstruction, the indication here



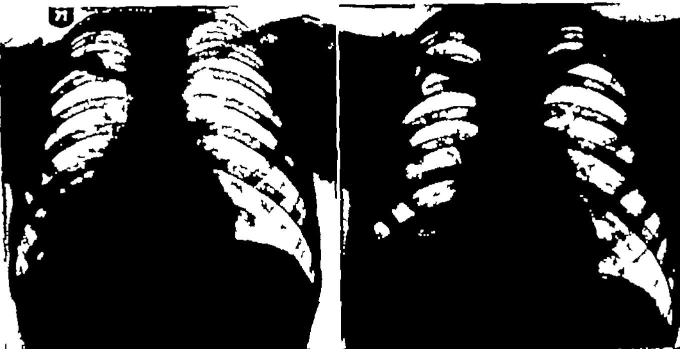
FIG 10 14—Complicated primary tuberculosis in addition to consolidation and collapse of the posterior segment of the right upper lobe there is obstinate emphysema of the right lower lobe

With the main aim of preventing collapse of the lower lobe and possible later permanent bronchiectasis thoracotomy was done (Mr K Roberts) A tuberculous abscess which had perforated the upper lobe bronchus was found The glands, abscess cavity and upper lobe were resected as the bronchial *involvement was too severe to allow conservation of the upper lobe* The child made a *good recovery* This might have resolved but the aim of surgery was to save the right lower lobe



FIG 10 15—Male infant aged 6 months, admitted as an emergency with acute dyspnoea and stridor following on a month's illness, having been in contact with his father suffering from open tuberculosis The radiograph in addition to characteristic "epituberculosis" of the right upper lobe, shows gross obstructive emphysema of the right lower lobe and of the left lung Emergency right thoracotomy showed caseating glands compressing the trachea into which perforation had occurred at the point of origin of the right main bronchus Excision of glands, suture of the perforation and temporary tracheotomy led to immediate relief Subsequently a good recovery with the aid of chemotherapy (Mr S J MacHale)

s to relieve a wheezing cough and to prevent the danger of total lung atelectasis (c) in collapsed lobes in children who continue to deteriorate in their general condition in spite of full chemotherapy in this condition at the operation there is almost invariably a rupture of the bronchial wall with much caseation in the lobe which often requires resection though ideally the operation should be one of adenectomy rather than lobectomy



(*a*) (*b*)

Fig 10-16

(*a*) A boy of 10 who in spite of three months full antibiotic and chemotherapy continued to go downhill with persistent pyrexia and loss of weight The radiograph shows disease of the right middle lobe At thoracotomy a large tuberculous abscess not only surrounded the middle lobe bronchus but had perforated it Right middle lobectomy The middle lobe beyond the site of tuberculous perforation was the site of pyogenic abscess formation.

(*b*) Radiograph two years later The boy has been well since the operation and leads a normal life

It must be emphasized that most patients with primary tuberculosis do well it is only in the exceptional instance that surgery of the type mentioned here is indicated the selection of patients for surgery is difficult a patient may rupture a caseous gland into a bronchus and complete cure may follow On the other hand not only tuberculous disease may persist in the affected lobe or lung but secondary persistent infection may be the cause of chronic ill health (Fig 10 16)

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CHAPTER 11

TUBERCULOUS DISEASE OF THE PLEURA AND CHEST WALL

PLEURAL EFFUSION

Primary effusions

Those though tuberculous in most instances do not arise as a complication of established pulmonary disease though they accompany or may follow a primary complex on the same or opposite side They are easy to diagnose and simple to treat their chief significance being that nearly one fifth of the patients with primary effusions develop obvious tuberculous lesions on the same or the opposite side within five years Many patients in recent years have passed from a Mantoux negative stage to a primary infection



Fig 11 1—A long-standing tuberculous empyema which followed a primary effusion.

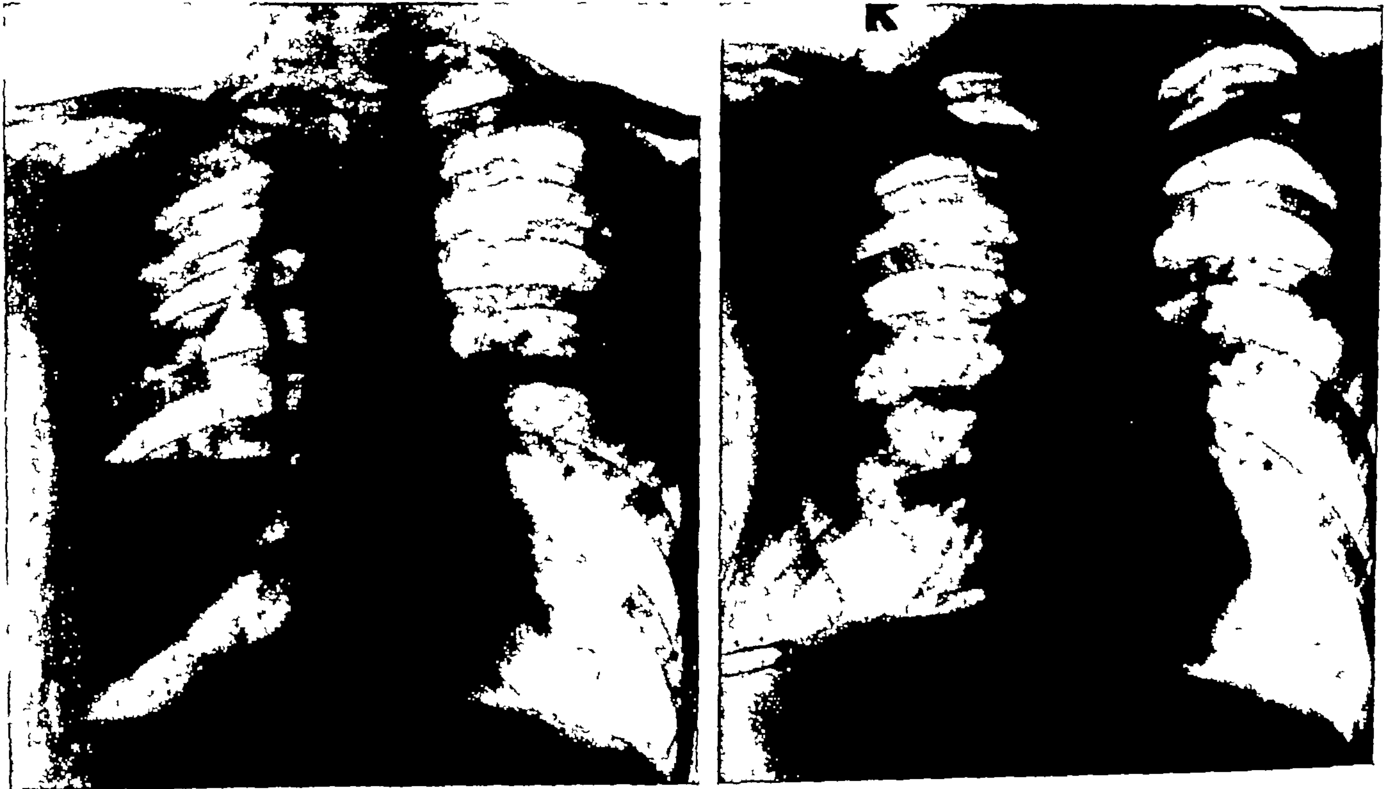
which has rapidly become complicated by a pleural effusion (Thompson 1949) Primary effusions usually absorb spontaneously aspiration is required for diagnostic purposes for the relief of dyspnoea and to aid absorption if this is too slow If all effusions are left to subside spontaneously by too simple a faith in rule of thumb methods an occasional patient is left with a compressed contracted lung and a flattened immobile chest wall with a highly placed rigid diaphragm and the loss of respiratory function may be a high price to pay for the over-studious application of the principles of rest

In modern practice there is no place for aspiration with air replacement in primary effusions simple paracentesis only being practised when fluid removal is indicated Bed

rest should be for a minimum of three months, streptomycin in combination with the usual drugs is given parenterally

Secondary effusion

This may arise spontaneously during the course of post-primary tuberculosis in the past it was a common complication of artificial pneumothorax It may be excited by the development of tubercles on the parietal and visceral pleura, from repeated trauma to adhesions during the phases of respiration, or as a complication of collapse of a lobe within a pneumothorax space



(*a*) (*b*)

Fig 11 2 —Radiographs of a male adult with pulmonary tuberculosis, (*a*) complicated by a spontaneous pyo pneumothorax, (*b*) satisfactory lung re-expansion after drainage

A persistent effusion is not unusual after a spontaneous pneumothorax of tuberculous etiology or after a lung air leak into a pre-existing pneumothorax space Effusion after thoracotomy for lobectomy, segmental resection or pneumonectomy is common, but rarely passes on to empyema formation unless a gross complication such as broncho-pleural fistula complicates the operations Thorough aspiration will be required for the post-operative effusions and streptomycin may be left in the pleura as a prophylactic measure

The differential diagnosis of pleural effusion

Serous effusions develop sometimes in congestive cardiac failure, constrictive pericarditis and with pneumonia, after lung infarcts, nephritis or in association with tumours of the ovary (Lawson Tait or Meigs Syndrome) With the increase of lung cancer effusions due to that disease are increasingly common If the effusion is serous and associated with a collapsed lobe or lung due to bronchial obstruction the condition must not be deemed inoperable on that account Blood-stained effusions in bronchial carcinoma, however,

almost invariably indicate inoperability. Spontaneous haemopneumo-thorax due to the tearing of adhesions produces a blood stained effusion which may be mistakenly regarded as malignant. Usually this condition produces severe bleeding with rapid deterioration of the patient's condition; its treatment often consists of early thoracotomy (Clyne and Hutter 1955).

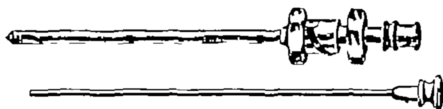


Fig. 11.3 (*a*)

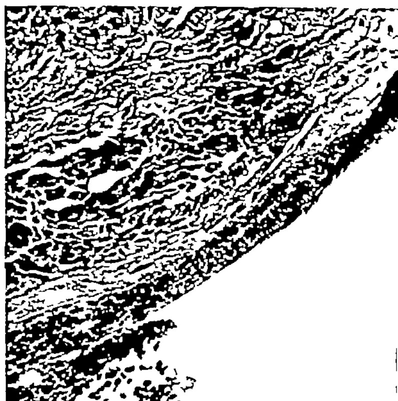


Fig. 11.3 (*b*)

(*a*) Pleural biopsy punch with the notch half open. The stilette which is always supplied has been removed. (G.U. Mfg. Co.)

(*b*) Carcinoma in thickened pleura from a patient aged 63, with straw-coloured pleural effusion.

Made by the Genito-Urinary Manufacturing Company, 28a Devonshire Street, London W.1. The type of syringe required should be specified when ordering.

In the diagnosis of malignant effusions clinical history and findings, radiology (after aspiration of the fluid), bronchoscopy and the search for malignant cells in the aspirate all play their part. Abrams (1958) has described a useful pleural biopsy punch which may often establish the diagnosis by allowing histological proof of carcinoma (Fig. 11.3).

The punch consists of an outer and inner tube, the former having a deep notch near its tip which can be closed by a sharp cutting cylinder on the latter. This action is controlled by twisting the back hexagonal grip. The illustration shows the notch half closed. When closed the punch

is airtight and can be introduced into the chest after a tiny incision has been made in the skin The aspiration apparatus is then attached and the notch opened The pin which controls the travel of the inner tube is held by a spring clip either in the open or closed position to prevent inadvertent movement When the aspiration is complete (the short trocar point does not damage the lung if the effusion is aspirated completely) the notch is directed along the intercostal space by means of the indicator knob on the front hexagonal grip and sideways pressure is maintained in this direction as the punch is withdrawn until the notch is felt to engage in the chest wall The back hexagonal grip is then twisted sharply clockwise so the cutting cylinder cuts off and holds the tissue in the notch The punch is then withdrawn and the biopsy found either in the hollow tip or in the inner tube from which it is cleared by the stylette

This instrument has enabled carcinomatous infiltration of the pleura to be demonstrated in cases of pleural effusion in which every other method of investigation has failed to reveal the cause Tuberculous pleurisy has also been demonstrated, and in cases with an adherent mass under the chest wall a good biopsy has been obtained by introducing the punch into the mass

Tuberculous empyema

Opaque pleural fluid containing a high cell count, a protein content higher than that of a serous transudate and tubercle bacilli is regarded as empyematous , when secondary infection, usually the result of a bronchopleural fistula is superimposed, the tubercle bacilli may disappear Most tuberculous empyemata used to be a complication of artificial pneumothorax treatment but are now usually due to broncho-pleural fistulae after resections.

Natural history of the disease. The fluid slowly becomes turbid and purulent, especially *if tubercle bacilli have been discovered while it was still thin and serous. Tuberculous pus* formation will be rapid when pleural infection follows the rupture of a cavity into the pneumothorac space or the tearing away of the lung attachment of an adhesion (Simmonds, 1941) The empyema, once developed, is a greater menace to life than the original lung lesion for which the pneumothorax or resection was selected

Seventy-four patients with tuberculous empyema were studied at Semb's Clinic in Oslo between 1941 and 1947 a follow-up of these in 1948 showed that 25 had died (Andersen, 1949) These figures are not much more encouraging than a mortality rate of 58 2 per cent in 79 cases reported by A Brian Taylor in 1932

Siddons and Konstam (1951) published a far better survival rate in 61 cases of tuberculous empyema and had only 4 deaths, the lowest death rate I can find in the literature , 55 of their patients represented complications of artificial pneumothorax The high mortality rate, it must be noted, was in patients treated by unsuitable pneumothorax therapy The problem has largely ceased to exist

Once a tuberculous empyema has developed, the course of the disease is downhill in most cases because of the increase of toxaemia, the result of absorption from the large pleural surface, the incidence of secondary pyogenic infection due to pleural fistula or massive atelectasis, and the increased risks of contra-lateral spread In addition there is a progressive loss of respiratory function, the result frequently of an unexpandable lung, and crippling of the chest wall In long persisting disease amyloidosis may develop. The outlook is specially gloomy if the pneumothorax has failed to control a parenchymal lesion of cavernous nature A review of the earlier radiographs in this type of empyema often revealed a cavity that would have been treated preferably by a primary thoracoplasty

If the lung does not re-expand fluid re-accumulates in spite of careful aspiration , a thick fibrinous envelope, later to be organized into dense fibrous tissue, develops on the visceral and parietal pleura The strangling effect of this fibrous layer on the lung further impedes the chance of the lung becoming adherent to the parietes and indicates that efficient treatment often consists of decortication or thoracoplasty If thoracoplasty is deferred too

late however drastically and thoroughly it may be executed complete obliteration of the infected pleural space may not be achieved

Secondarily infected tuberculous empyema

Many tuberculous empyemata follow the rupture of a small tuberculous lung focus that is peripheral and sub pleural and without a large bronchial opening Larger foci or actual cavities that break down give rise to broncho-pleural fistulae which carry the grave risks of a complicating secondary pyogenic infection This major catastrophe is accompanied by a dramatic clinical deterioration illustrated by a sudden malaise a high temperature and loss of appetite this is usually followed by the expectoration of large quantities of pus the other lung remains in constant danger of an acute bronchogenic spread of disease The treatment of this grave complication must be thorough and prompt and drainage or even such major procedures as resection of the lung may be required

All secondarily infected empyemata should be assumed to be associated with a fistula the gravity of secondary infection is reflected in a mortality rate of 90 per cent in those patients who are not fit enough to undergo thoracoplasty or more recently pleuro pneumonectomy (Sarot 1949)

Treatment

This may be (*a*) prophylactic (*b*) conservative (*c*) surgical.

(*a*) **Prophylactic treatment** Since unsatisfactory artificial pneumothorax is the commonest cause of empyema the selection of patients for a treatment of such potential danger must be scrupulous Empyema after resection operations are becoming rare since adequate chemotherapy has been used for a long period before surgery

(*b*) **Conservative treatment** Ineffective therapy is indicated in the literature by a multitude of suggested systems often of great complexity They are rarely in use today The aim of conservative treatment is the same as that attempted surgically namely the obliteration of the pleural space If a pleural effusion potentially purulent or a true empyema is developing every effort is made to secure lung re-expansion the fluid is aspirated and antibiotics used to sterilize the pleural cavity

Before embarking on the medical treatment of tuberculous empyema by aspiration and the instillation of antiseptics or antibiotics the ultimate aims and hopes must be clearly considered If a pneumothorax now complicated by effusions or empyema has failed to control the underlying disease in the lung neither condition will be cured by conservative measures

The best chance of recovery depends on major surgical measures provided the other lung is sufficiently stable In such patients aspirations and intrapleural chemotherapy are useful preparatory measures which must not be used too long because delay may lead to multiple cutaneous fistulae through the aspiration sites or encourage such thickening of the pleura that even the most radical thoracoplasty will fail to close the pleural space

In patients with a favourably controlled lung lesion within the infected pleural space early aspiration may control the infection and enable a satisfactory pneumothorax to be maintained though this is quite exceptional The important measures in such patients include complete bed rest and repeated aspirations under radiological control The aspiration sites should be so selected that if they become infected this will not interfere with the plan for later thoracoplasty If the fluid is too thick for needle aspiration the use of a thoracoscopy cannula placed high up anteriorly may enable a suction tube to aspirate

all the thick products in the lower pleural cavity Thorough aspiration is the key to success and exceeds in importance the use of any sterilizing solution, though streptomycin and para-aminosalicylic acid placed intrapleurally are of value

Siddons and Konstam (1951) have recorded satisfactory results of aspiration in the treatment of empyema uncomplicated by patent cavities and a persistent broncho-pleural fistula Their results are due to excellent technique in aspiration which is thorough and aided by the study of the levels and depths of the effusions as seen on radiographs taken a day after the injection of radio-opaque oil into the pleural cavity They emphasize the need for thoroughness in aspiration and for the immediate adoption of major surgical measures when the contra-indication to aspiration treatment exists (patent cavities, persistent fistulae, inexpandable lungs)

(*c*) **Surgical treatment.** The surgical aims in the treatment of tuberculous empyema are the same as in the management of pyogenic empyema, namely, the removal of pus and the obliteration of the pleural pocket In tuberculous empyema the chief difficulty is to obtain expansion of a lung that is actively diseased or has suffered great loss of elastic tissue as the result of the fibrotic healing of disease or secondary to the stenotic healing of a tuberculous endobronchitis Moreover, the lung may contain a focus that constantly re-infects the pleural cavity either through a fistula, or a ruptured cavity, or from an infected collapsed lobe or lung This latter condition may be compared with the empyema that may complicate a permanently collapsed upper lobe after a lobectomy for basal bronchiectasis, the cure of which will entail a residual lobectomy

The removal of the empyema fluid For the simple pure tuberculous empyema, needle aspiration is employed before and during thoracoplastic procedures and surgical drainage is avoided as far as possible In secondarily infected pyo-pneumothorax, however, intercostal drainage may be required to save life, and the toxaemia from the suddenly flooded pleural cavity resembles that seen in putrid empyema, the result of a ruptured lung abscess

The site of drainage should be selected with the thought in mind that later a thoracoplasty or a lung resection operation will be required and the drainage must be of the water-sealed variety to encourage lung re-expansion as much as possible Occasionally this drainage will be followed by lung re-expansion and obliteration of the pleural space but this happy result is a rarity

Major surgical measures for tuberculous empyema

The obliteration of the total pyo-pneumothorax space is hindered by a grossly thickened parietal pleura and a collapsed lung, so that a residual space is often left even after a most radical thoracoplasty of four or five stages, including anterolateral as well as extensive posterolateral rib resections Especially distressing at the end of these major interventions is the persistence of a drained empyema space which may necessitate a permanent tube These extensive thoracoplasties can sometimes be avoided by the use of pleuro-pneumonectomy

A complete achievement of pleural symphysis is far more likely if the thoracoplasty is commenced as soon as the patient is fit for operation It is unwise to persist too long in efforts aimed at securing lung re-expansion, by repeated aspiration, or closed drainage, for the delay often produces an unnecessarily thickened pleura that will not collapse after the most extreme rib resection If for good reasons the delay has been inevitable, total obliteration may only be possible by combining the thoracoplasty with a pleural decortica-

tion If the residual cavity is of moderate size it may be opened widely from its apex to its base and treated by packing in the hope of cure by eventual cicatrization of granulation tissue

If the underlying lung contains a large fistula or has residual cavitation total excision of the lung and infected pleura (pleuro pneumonectomy) is far more effective and has largely replaced thoracoplasty In favourable cases the resection may be confined to a lobectomy followed by a partial thoracoplasty after the remaining lobe has been decorticated

Thoracoplasty

Preparation of the patients by aspiration and not drainage is the aim in tuberculous empyemata the secondarily infected patients usually will have been drained The general condition of these patients is often poor and amyloid disease may have commenced it is important not to regard this as a contra indication, for there is evidence that the process is reversible if the infection is eradicated or controlled and the onset of this degeneration is indeed an indication for urgent major surgery It hardly ever occurs in the absence of tuberculous infection being seen most commonly in the chronic secondarily infected pyo-pneumothorax

The pre-operative measures include attention to the state of the blood picture and to the improvement of the usual hypoproteinaemia the full pre-operative course of nutritional therapy is adopted

Anaesthesia and posture on the table Local anaesthesia is advisable if the thoracoplasty is being done at a comparatively early stage of empyema formation but will be replaced by general anaesthesia when chronicity has caused great thickening of the parietal pleura with overlapping of the ribs for this combination prevents efficient local anaesthesia and creates special surgical difficulties which militate against gentle stripping and elevation of the ribs

(If a broncho pleural fistula is present the usual posterolateral position places the sound underlying lung in great peril from the risk of spill-over infection) in a patient with a totally collapsed lung the danger may be overcome by the use of Thompson s blocker but the prone position or one in which the patient is propped up high in the anti Trendelenburg position is usually the best answer to the difficulty

The operation The amount of rib to be resected must be extensive and staging of the operation is essential to avoid severe surgical shock At the first stage the first three or four ribs are removed sub-periosteally from the level of the transverse process to the cartilages If the empyema space reaches to the clavicle or higher the performance of a Semb s extrafascial apicolysis has great merit and facilitates the start of pleural symphysis the result may be so satisfactory that frequently it enables a stage to be avoided, as the dropping of the pleural dome does much to decrease the size of the empyema The extrafascial fibro-muscular bands are greatly hypertrophied evidence of the part they play in maintaining elevation of the apex of the empyema pocket If a cavity is present in the apex of the lung the addition of this apicolysis is an essential step

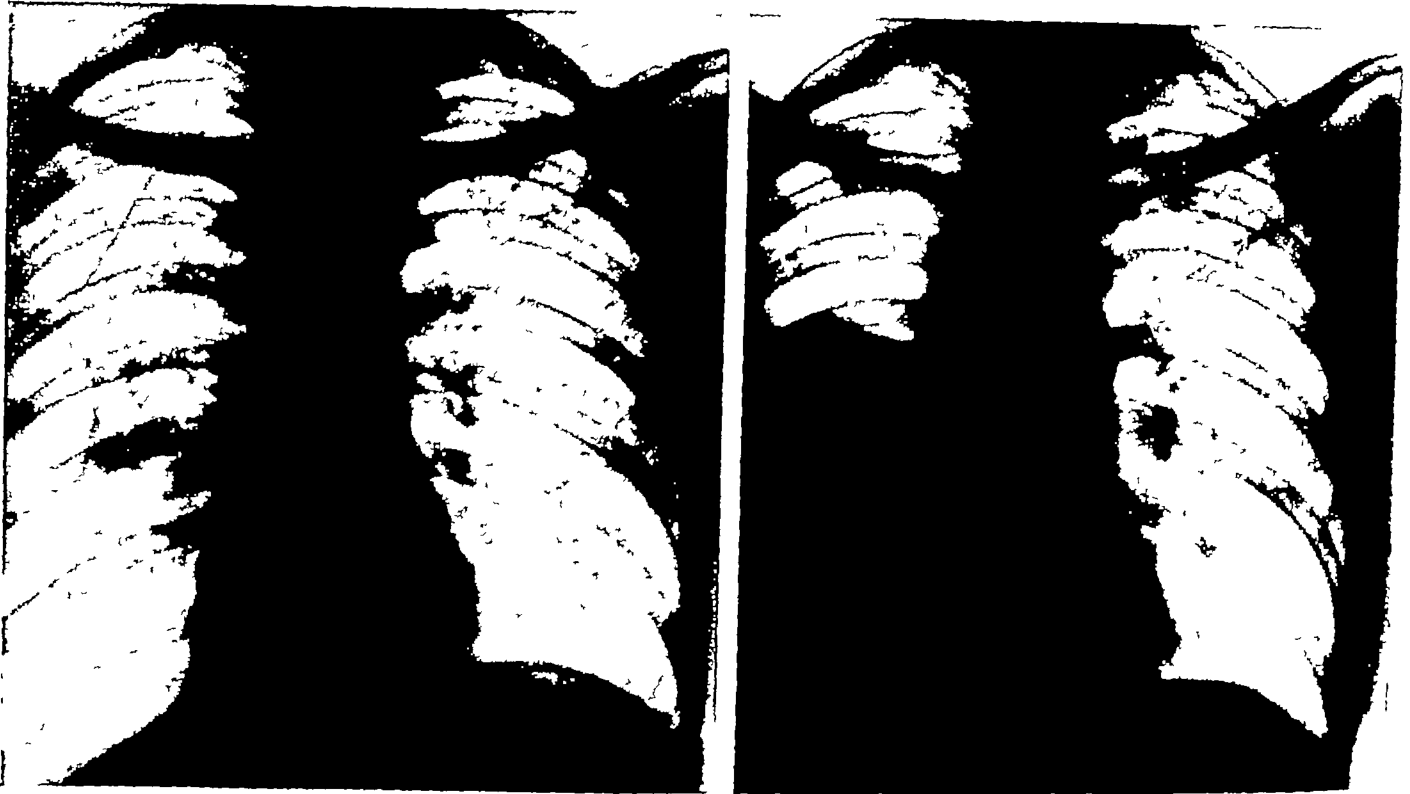
The later stage of the operation involves a resection of ribs greater in extent than that required in thoracoplasty for parenchymal disease Fortunately there is rarely trouble from paradoxical respiration because of the rigidity of the pleura and the mediastinum

The addition of an anterolateral stage is indicated if two weeks after the completion of a radical posterolateral thoracoplasty the radiograph reveals a cavity that is not rapidly closing If this stage is delayed too long the regeneration of the ribs excised at the first and second stages will prevent further adequate collapse

Decortication

Excision of the thickened visceral pleura enveloping the lung in chronic non-tuberculous empyema has been practised for many years (Delorme, Ransohoff, Hedblom), and it has been applied to tuberculous empyema more recently because of the disappointments after many extrapleural thoracoplasties and because a successful result by this method is achieved with less mutilation and deformity and possibly with some improvement in lung function

(1) Decortication alone is the operation of choice for an unexpandable lung in which



(*a*) (*b*)

Fig 11 4

(*a*) A long-standing right pneumothorax of 8 years
Upper lobe would not re expand Left phrenic avulsion had been performed for left apical disease

(*b*) Spontaneous pneumothorax into right pleural cavity followed by secondarily infected pyo-pneumothorax
An indication for thoracotomy and decortication

limited disease had healed under a pneumothorax that unexpectedly became complicated by an effusion, which, though readily controlled by aspiration, led to a progressive deposit of fibrin on the pleura If full re-expansion can be obtained, as is usual, by a single operation, without re-activation of disease, the advantages over a full thoracoplasty are obvious

(2) Decortication combined with an upper partial thoracoplasty has an important place in the treatment of a tuberculous empyema that has arisen from the following set of misfortunes · an artificial pneumothorax induced for upper lobe disease, with correct or incorrect indications, may suddenly cease to be selective if the lower lobe collapses, failure to obtain re-expansion of this lower lobe by abandonment of the pneumothorax is often followed by an effusion that may proceed to pus formation The inability of the lobe to re-expand is due to its distortion and imprisonment by fibrin deposition which becomes organized into dense fibrous tissue A successful decortication followed by an upper thoracoplasty will lessen deformity, save the need for multiple operations and if performed sufficiently early may restore some respiratory function to the lower lobe

(3) A third use for decortication is in combination with an upper lobectomy An ill applied artificial pneumothorax for an upper lobe tension cavity may be followed by effusion and empyema formation sometimes with rupture of the cavity The previously healthy lower lobe after decortication of its fibrinous envelope may be conserved while the upper lobe is resected Occasionally the re-expanded lower lobe may adequately fill the hemithorax without producing undue distortion of the mediastinum and the other lung If however this is not achieved or because the other lung has been the seat of disease that may be adversely affected by over-distension the result of a mediastinal shift to the lobectomy side, an upper thoracoplasty is indicated

(4) *Decortication can be employed with success in patients with unexpandable lungs* of long duration who suddenly develop a pyogenic empyema

(5) A basal empyema cavity remaining at the completion of an extensive staged thoracoplasty may be obliterated by a partial lower lobe decortication in preference to a myoplasty or Roberts s flap operation The aim in these operations is really the total excision of an empyema through the extrapleural plane and the cavity can at times be removed without being opened.

Contra indications to decortication

(*a*) The chief obstacle to a good result is extensive disease in the collapsed lung the existence of this may be estimated radiologically by the presence of tubercle bacilli in the sputum and the demonstration of a lung cavity by means of tomography Tubercle bacilli in the pleural fluid are not a contra indication.

A lung collapsed by artificial pneumothorax does not necessarily undergo fibrosis after many years of passive collapse the alveoli may reopen and their blood supply and functional capacity return the histio-cytic proliferation of the walls of the alveoli the change in the shape of the capillary blood vessels and the increase of connective tissue in the peri vascular and peri bronchial spaces may all return to normal structure (Vorwald A J quoted by Gordon and Welles 1949)

Extensive disease of the lung undergoing pneumothorax collapse will however be replaced by fibrous tissue and this may have destroved the elasticity of the lung so that its re-expansion *will not follow and the attempt to make it do so might well re activate* tuberculous disease

(*b*) Stenosis of the main or lobar bronchus is an absolute contra indication to decortication consequently no decortication should be attempted until a bronchoscopic examination has been done

Objections to decortication

(*a*) *Risk of infection* Not *easily* can the reluctance to operate on tissue containing tubercle bacilli be shed. But the disastrous results which in the past followed the accidental opening of tuberculous lung tissue do not seem to follow deliberate operations such as Monaldi drainage or lobectomy or pneumonectomy and the theoretical dread that extensive removal of tuberculous pleural tissue will lead to spread and re-activation of disease has not been supported by the results of decortication in the treatment of pleural empyema provided active diseased areas in the lung are not opened in such a way as to provide a continual escape of bacilli It is difficult to estimate the degree of safety conferred by streptomycin but most of the good results published have been from patients who have received this drug locally and generally

(*b*) *Failure to restore function in the decorticated lung* Radiological evidence of sat factory re-expansion is no criterion of a similar return of function ; this affords a disappoi ing contrast with the physiological improvements that follow decortication performed ea for the release of lungs imprisoned by a fibrinous envelope, the sequel of a clotted haem thorax or developing in a subacute pyogenic empyema , perhaps the lack of improveme in the respiratory physiology of a tuberculous lung that has become unexpandable after pneumothorax is due to the underlying parenchymal disease that has been followed in t healing process by a replacement fibrosis that prevents a reversion to a more normal sta Respiratory studies often show a dramatic improvement in the maximum breathing capacit in the division of lung volumes and in the arterial oxygen saturation after a satisfacto therapeutic pneumothorax has been abandoned with good lung re-expansion The san cannot be predicted in all patients treated by decortication with a good radiological resul and in some the respiratory function is actually depressed Lacking, as we still do, sufficie data based on the modern tests for function after decortication, it is only possible to indica the present trend of the findings In more than half of the patients treated the maximu breathing capacity shows a deterioration , in a third the total lung volume shows an increa after operation but not necessarily with any improvement in ventilation But the strikin disappointment is reflected in the frequent evidence of a decrease in the arterial oxyge saturation This hypoxia is accentuated when the subject is doing exercise during th investigation

The decrease in the arterial oxygen saturation may be due to one of two factors, or t a combination of both With the re-expansion of the lung more blood enters it through th pulmonary artery because the channels of the arterial bed have been re-opened as a resul of the re-expansion this extra blood fails to be adequately re-oxygenated either becaus the lung ventilation is too poor to permit an adequate arterial-oxygen exchange or becaus the long-continued collapse and the underlying disease has altered the character of th alveolar walls, preventing the normal gaseous interchange at that level The poorly oxygen ated blood then flows through the pulmonary veins to mix with that from the sound sid and the general arterial oxygen saturation is lowered

Disappointing though these physiological results may be, the obliteration of a pyo pneumothorax removes far greater dangers than those likely to follow a minor degree o hypoxia, and the physiological findings are not sufficient to justify the withholding of th operation with its proved benefits

The operation. Pentothal, curare and oxygen with controlled respiration provid satisfactory anaesthesia The positioning on the table depends on the presence or absence of a fistula and the contents of the empyema space After the fluid has been completely aspirated, the chest should be opened in the head high position, or in the prone Sellors-Overholt position, until all the pleural contents have been sucked out

A wide thoracotomy through the bed of the resected fifth or sixth rib gives good access and multiple resections are not required When the empyema space has been sucked out and mopped dry, the pearly grey membrane will be seen covering and obscuring all normal anatomical structure including the lung, pericardium, diaphragm and the parietal pleura Between this dense opaque tissue lies a plane of cleavage between the pleura, visceral or parietal, which is crossed by fine vessels to expose this plane more than one exploratory incision through the rind of dense fibrous tissue may be needed before the shiny bluish pleura is seen The incisions made with a scalpel should be long when the edges of the incisions have been separated by blunt dissection, they are held up on each side by several artery forceps, and if the correct plane has been reached it is developed by blunt dissection

carried out largely by pledglets mounted on long slightly curved artery forceps of the Tudor Edwards's type aided by the use of scissors Slight oozing of blood and frequently the escape of small bubbles of air are inevitable as the delicate communications between the peel and the pleura overlying the lung are severed. If at any area this appears to be unduly evident a moist gauze pad is left there and the dissection proceeded with elsewhere If extreme areas of adherence to the underlying lung are encountered a circular cut round the fixed spots is made and the cicatrized patch of pleura left *in situ* this is frequently required over the upper lobe when as is usual this has been the seat of disease calling for the original pneumothorax and it is obvious that the greatest care must be exercised in the peeling of tissue from any area known to have been involved in tuberculous disease

The decortication must be thorough and the whole lung should be mobilized and the interlobar fissures completely freed Frequently the lower lobe will be found to be twisted so that its basal margin may be fixed to portions of lung above and anteriorly Similarly the apex of the lower lobe is often held captive in a downwards position and it must be freed on all sides and the fissure between it and the upper lobe cleared

Once an adequate stripping has been secured it is a great help to have the lung re-inflated by the anaesthetist and this assists in the further dissection while the edges of the peel to be removed are held upwards Any linear tear in the lung tissue is repaired by fine silk or cotton sutures and fibrin foam or fine layers of oxycel gauze are useful adjuncts in checking undue oozing The lower lobe must be freed completely from the diaphragm which itself is thoroughly decorticated

The extent of decortication will be indicated by the needs of the particular case if the aim is to limit the extent of a proposed or already partially executed thoracoplasty only the lower lobe will be cleared combined with an upper lobectomy for persistent cavity or fistula formation the stripping will be equally restricted though in some instances decortication of the lobe to be excised may be required in the region of the hilum to expose the structures to be isolated unless a pleuro-lobectomy (see later) is to be performed

Excision of the false membrane from the parietal pleura Grossly thickened parietal pleura may be an important factor in delaying the restoration of chest wall movements important in aiding re-expansion and restoring respiratory function moreover the membrane may be the site of tubercle formations and it is often advantageous to remove it entirely The disadvantage of this extension of the decortication is that heavy bleeding may be encountered for the plane of dissection must be through the endothoracic fascia a tissue rendered abnormally vascular by the severity of the adjacent pleural infection It is impossible to secure the same plane between the organized peel ' and the parietal pleura as it is on the lung surface and the parietal membrane is included in the stripped tissue

If the decision is made to remove the parietal thickening it is well to start the whole process of decortication on the parietal surface which is well stripped off the chest wall before the empyema cavity is opened as the place of separation between this layer and the visceral one is readily found as a thickened ridge where the two meet and the dissection can proceed rapidly on to the lung surface Occasionally it is possible to remove the whole empyema space unopened

Before the chest is closed all bleeding must be checked chiefly by the use of hot saline compresses the space is drained by two catheters one introduced apically and one posteriorly at the base and these are connected on return to the ward to a water sealed drainage system which can be made negative by the use of Roberts's suction motor pump (see Fig 6 7)

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PART IV

CHAPTER 12

NEOPLASMS OF THE LUNG AND TRACHEA

MALIGNANT TUMOURS OF THE LUNG

Primary bronchial carcinoma is clearly the commonest tumour encountered but secondary metastatic neoplasms are not infrequent and must be remembered when peripherally placed masses or diffuse infiltrations are under consideration. Benign tumours are not common (about 4 per cent of all lung tumours) but more are detected annually as the result of the extended use of radiography and bronchoscopy of this group bronchial adenoma is the most important Whatever its true pathology it can be separated clinically from bronchial carcinoma by differences of age sex incidence and natural history, of which the most important feature is the prolonged survival of many of its sufferers with or without treatment

Metastatic lung neoplasms

Although sarcoma especially of bone is usually fatal because of lung secondaries which cause haemoptysis and give rise to typical circular shadows often multiple on the radiograph (Fig 12 1) it is in carcinoma that most lung metastases have their origin and the primary seat of growth may be one of many organs such as the breast kidney testis ovary and uterus In all peripherally sited circular tumours a thorough examination of the whole body is essential to exclude a primary growth elsewhere

Metastatic involvement of the lung may be in the nature of a diffuse infiltration presenting clinically as an intractable pulmonary fibrosis causing an obstinate hard dry cough and dyspnoea the X ray changes are often equivocal It is important to remember that such infiltration may develop many years after a successful mastectomy for cancer of the breast or in patients with gastric and other abdominal cancers

Many records now exist in which solitary secondary tumours have been removed by lobectomy or pneumonectomy and some long survivals have been noted when the primary growth has been removed also * but usually the metastases are multiple and clearly the greatest care must be exercised so that unnecessary suffering is not caused by futile attempts at palliative surgery If the metastasis is solitary and is causing symptoms such as haemoptysis eradication is indicated I have several three year survivals after resection of solitary metastases following previous resection for carcinoma of the colon uterus and bladder Hood (1955) and others from the Mayo Clinic reported on their results in 43 patients 33 per cent survived three years and 27 per cent five years after resection of pulmonary metastases for carcinoma or sarcoma

Metastasis of cancer from one lung to the other is unusual though involvement of the lymph nodes at the hilum is common The metastasis in the left lower lobe illustrated

* Tudor Edwards (1940) described a patient who was well 18 years after a partial lobectomy done for a deposit secondary to a sarcoma of the fibula. Seila, Clagett and McDonald (1950) have reviewed 92 resections, including 10 from the Mayo Clinic: the results were encouraging

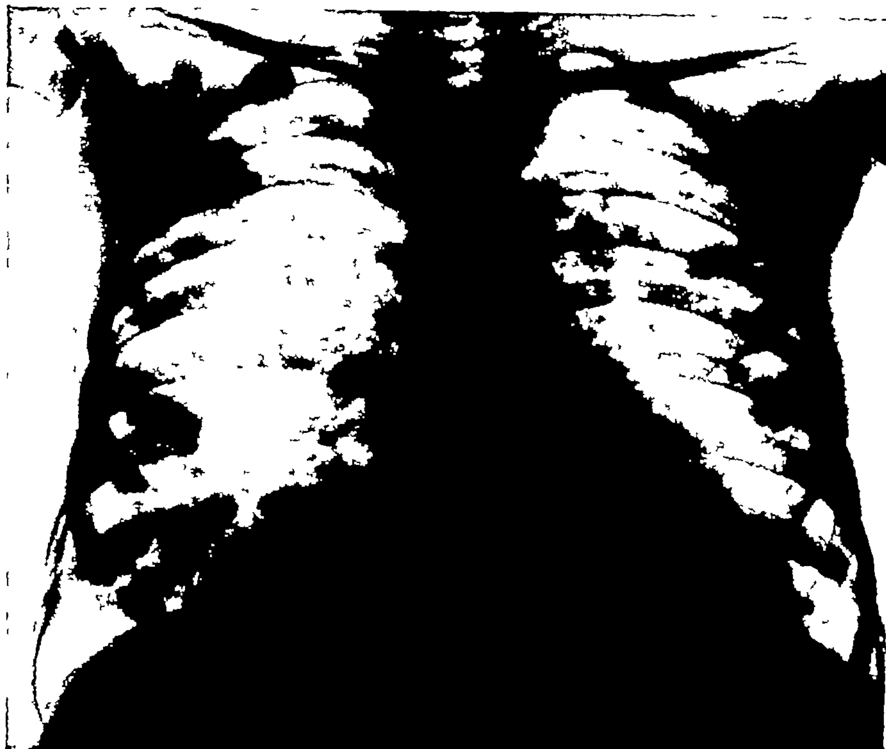


Fig 12 1 —Lung metastases secondary to an osteogenic sarcoma of the thigh



Fig 12 2



Fig 12 3

Fig 12 2 —Radiograph of metastatic lung tumour secondary to uterine sarcoma
The lung metastasis was removed by lower lobectomy

Fig 12 3 —Circular metastatic tumour in left lower lobe
Right pneumonectomy a year before for carcinoma of right main bronchus

in Fig 12 3 is unusual and developed in a man of 60 a year after right pneumonectomy for carcinoma of the main stem bronchus Occasionally both lungs are permeated by carcinoma spreading along lymphatic channels often from a small growth in one side such lesions may be mistakenly regarded as fibrosis or chronic pulmonary tuberculosis

Primary bronchial carcinoma

Lung cancer is now the commonest malignant tumour to affect males in Great Britain the incidence has shown a steady rise in the last 25 years this rise is not only attributable to better diagnosis following the increased use of radiology and bronchoscopy but seems to be genuine

Stocks (1947) believes there is a true increased incidence in the last 30 years and that this is not due to better diagnostic facilities though obviously more patients are accurately diagnosed now He indicates that deaths from lung cancer have not only increased in absolute figures but in proportion to cancer of other sites

Even if all the old faulty diagnoses of sarcoma of the mediastinum' of lymphosarcoma and Hodgkins disease were accepted as bronchial carcinoma from hospital and autopsy records its incidence 25 years ago was relatively small. The increasing frequency of the disease the hopelessness of the prognosis without adequate surgery and the absence of a clear-cut symptomatology of this disease makes its study of great importance

Its incidence is rising in most parts of the world being highest in England and Wales In comparing the rates with those of the U.S.A. the incidence in females is very similar but is higher for males in England and Wales (See Table VIII)

The problem as presented at the Birmingham University Hospitals is shown strikingly by the fact that in 1946 137 patients were diagnosed as having bronchial carcinoma and in 1952 the figure had risen to 418 In the Birmingham Regional Area (about four million population) including those patients seen at the University Hospital 201 were diagnosed in 1946 as against 748 in 1952 These figures continue to rise *

Etiology The rapid increase in the incidence of bronchial carcinoma has led to enquiry into any specifically modern irritant tobacco smoking petrol fumes dusts especially bituminous road surfaces and industrial dusts have all been suggested as the accusative irritants, but the evidence is too complicated to discuss in a surgical work at the moment of writing the blame attached to tobacco smoking is significant Doll and Bradford Hill (1950) after a thorough statistical survey say that smoking is an important factor in the production of carcinoma of the lung and the evidence presented in their article is powerful The contrast provided by figures from Iceland where smoking is not common is striking for Dungal (1950) pointed out that in the records of 1 930 autopsies performed in Iceland between 1932 and 1948 there were only 12 examples of bronchial cancer out of a total of 417 malignant growths this is a small proportion compared with figures from other Western countries where smoking has been common since 1914

Although cancer of the lung may develop in the second decade of life it is at present most commonly seen between the ages of 40 and 70 The preponderance of males is striking but the etiological sex difference is as yet unexplained

Occupational hazards In the mines of Schneeberg lung cancer is common and over half the miners there die of the disease An inhaled, carcinogenic irritant can be assumed to be an operative cause The dust in these mines contains a great variety of potential irritants such as arsenic cobalt silica and radio active substances such as uranium

* These figures and others quoted in this chapter were obtained by Miss Levi of the Cancer Follow up Department of the United Birmingham Hospital

Irritating substances produced in the chromate industries have been under close observation. Machle and Gregorius (1948) found that the mortality of lung cancer in chromate workers over 50 years of age was 40 times that of workers in comparable industrial groups. They pointed out that an average of 14.5 years' exposure to the industrial hazard was necessary before carcinoma developed and this agrees with the modern view that carcinogenic dangers may be of slow evolution as in carcinoma of the cervix in women.

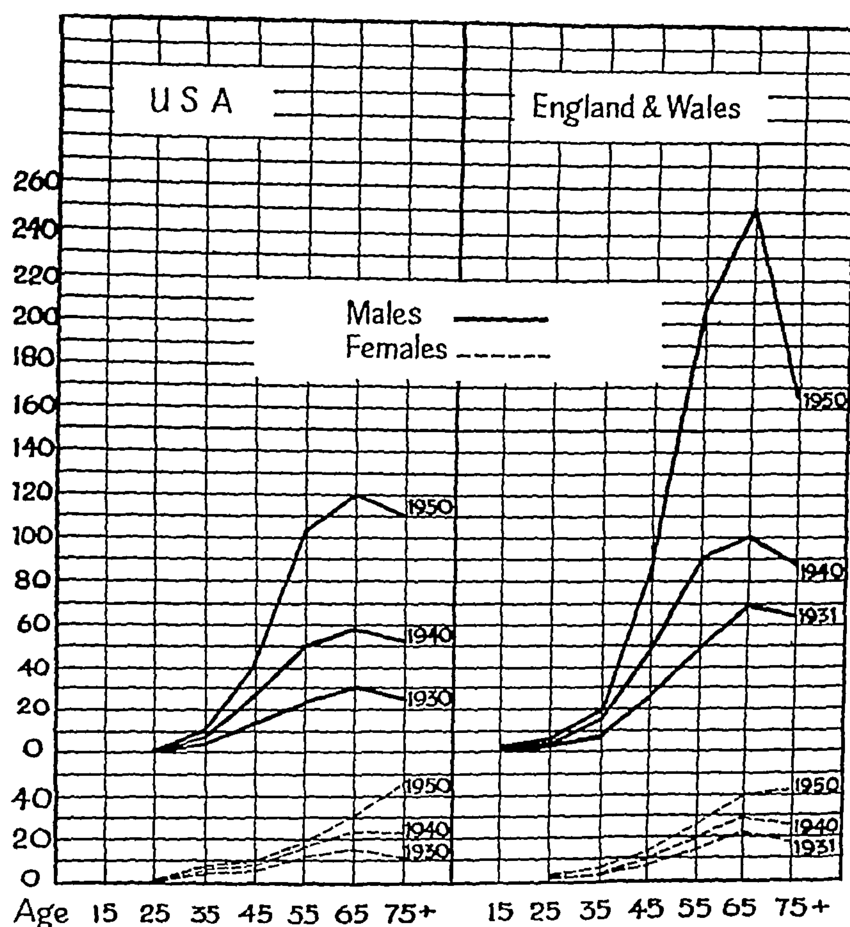


TABLE VIII

Environmental factors. The larger the city, the higher the death rates from lung cancer. Clearly this might be attributable to the better diagnostic facilities and the availability of autopsy and operation room records in the larger centres. But such an argument is faulty when comparing the death rates in a residential town like Bournemouth with those of an industrial Huddersfield; the death rate figures in such comparison are greatly loaded against the industrial region. Stocks, in explaining these differences, says "either smokiness of atmosphere is an important factor in itself in producing lung cancer or sunshine is an important factor in preventing its incidence." His evidence as summarized by Taylor and Waterhouse (1950) is as follows; there is a marked fall in death rate in relation to the hours of sunshine recorded. When 20 large county boroughs were divided into three groups by their mean annual sunshine hours, the lung cancer mortality ratios (taking all county boroughs as 100) were as follows:

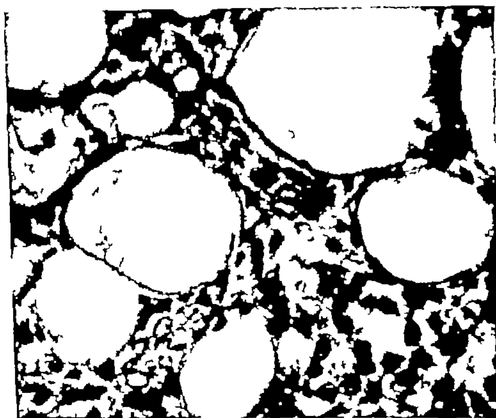
	Hours' Sunshine	Cancer Mortality
Group I	Under 1,150	152
Group II	1,150–1,400	100
Group III	Over 1,400	58



(*a*)



(*b*)



(c)

Fig 1 4

( ) Squamou cell carcinoma (× 1?0).
(b) Oat-celled carcinoma f bron hu (× 38). (Prof J W Orr)
(c) Adeno-carcinoma of bronchu with mucoid degeneration (× 500). (Prof J W Orr)

When these same 20 boroughs were divided into two groups, coastal and inland, the average ratios (to all county boroughs—100) were

Sea	66
Inland	138

There seems little doubt that lung cancer is commoner in the large industrial towns than in the coastal towns that are not industrial nor could anyone knowing the high standard of medicine in large seaside towns believe that patients there are less well investigated But coastal position is by no means the only factor for Liverpool has a high incidence of lung cancer

Pathology All lung cancers are probably bronchiogenic and their origin from the alveoli is considered to be unlikely The tumours may be squamous in type or columnar celled, though one tumour may show cells of both types Many tumours previously dubbed as " mediastinal sarcoma " or " pleural endothelioma " are now known to be bronchiogenic carcinoma

Occasionally reports appear on the condition of " pulmonary adenomatosis " in humans and this has been compared with the condition known as " Jaagsiekte " which occurs notably in sheep and dogs and may be infectious in origin In the human there is undoubtedly a malignant diffuse growth in which the macroscopical appearances are those of a lobar pneumonia , on histological examination the alveoli appear to be filled or lined with columnar mucus-secreting cells and this has led to the suggestion that the state is really one of alveolar-celled carcinoma , most pathologists, however, believe that these cells in the alveoli represent down growths of malignant cells whose true origin is in the epithelium of the bronchioles The condition has been discussed by Dacie and Hoyle (1942) and Paul and Ritchie (1946) A study of the reported cases does little to support the possibility that malignant disease can develop from lung alveoli

Another cause of confusion is the description of malignant tumours as " pleural endothelioma " , in this condition the lung and pleural membrane is enclosed in a sheath of malignant cells Careful histological study of these cells indicates that they are bronchial in origin and the term is in increasing disfavour, though true instances undoubtedly exist

Nomenclature The confused naming of different types of lung cancer depends on the frequent presence in any one tumour of different types of cell which themselves may have undergone varying degenerative or metaplastic processes , a squamous carcinoma may have areas of undifferentiated cells of an oat-celled or mucoid type Nevertheless an attempted classification is useful if it is remembered that many tumours cannot be segregated into water-tight compartments The commonly accepted trio are (I) squamous-celled carcinoma (epidermoid carcinoma), Fig 12·4 (*a*), (II) undifferentiated carcinoma, Fig 12 4 (*b*), and (III) adeno-carcinoma, Fig 12 4 (*c*)

Between 1947 and 1952 at the United Birmingham Hospital, histological examination of 790 cases was made 349 (44 per cent) were squamous cell carcinoma, 398 (50 per cent) were anaplastic, undifferentiated carcinoma and only 43 (6 per cent) were adenocarcinomatous The squamous cell tumour probably provides the best prognosis after resection From the surgical point of view it is well to remember that a portion of tumour removed by biopsy through the bronchoscope may be unrepresentative and thus it is unwise to base prognosis on such sections

The account given above may have the defect of over-simplification and is based largely on the histological examination of pneumonectomy specimens This tends to lower the incidence of " oat-celled " carcinoma, as this tumour often provides a high quota of

inoperable patients Bryson and Spencer (1950) in an analysis of 866 fatal cases of bronchial carcinoma classified the tumours under five headings as follows

Type of Growth	Number of Cases	Percentage
Oat-celled	312	36
Polygonal-celled	348	40
Squamoid	97	11 2
Squamous-celled	60	6 9
Adeno-carcinoma	42	4 9
Unclassified	7	0 8
	866	

These authors were however rigid in their selection of cases deemed suitable for classification as squamous tumours and excluded all from that group unless the microscope showed prickle cells or keratin they agree with other writers that bronchial carcinoma is notable for the extreme pleo morphism of its histological structure



FIG 12 5—Radiograph of superior sulcus tumour causing opacity at right apex. The patient a man of 4 complained of severe brachial neuritis he had a Horner's syndrome

The tumours may be peripheral in a large bronchus (many lung cancers are in areas of the bronchial tree visible at bronchoscopy and are suitable for biopsy) or in a small bronchus When located close to the mediastinum that area may be rapidly invaded especially by oat-celled carcinoma in the younger patient

Over three quarters of the tumours develop in a large bronchus with the right lung more frequently affected than the left Simons (1937) in a series of 2 177 found the right lung was affected in 1 147 but in the same group the left upper lobe was more often affected than the right upper one

scope this examination is essential when symptoms and radiology have suggested a possible neoplasm The method is safe and simple and can be carried out under local anaesthesia. Moreover in most stem growths a biopsy can be taken and histological evidence of the exact type of tumour obtained Even when the growth itself is not visible distortion or bronchial occlusion from the extrinsic pressure of a tumour may support a pre bronchoscopic suspicion of growth.



FIG 12 12.—Pneumonectomy specimen.
Note that bronchiectasis has developed in the lower lobe from the bronchial obstruction.
(Photography by Dr Cruikshank Hill Top Hospital.)

The assessment of operability by the bronchoscope Important signs of inoperability are a paralysed vocal cord or spread of growth to the trachea If the mediastinum is extensively invaded the bronchi are rigid and fixed and the carina may be bulged upwards by tumour invasion of the inferior tracheobronchial glands Exceptionally the growth may have spread over the bifurcation into the opposite bronchus

Cytological examination of the sputum and other histological methods The examination of the sputum by the wet film method so earnestly advocated in this country by Dudgeon (1935) and consistently supported by Barrett has at last been adopted and as high a proved rate of 80 per cent has been achieved by some workers The technique and reading of the film requires great experience and morning specimens of sputum should be carefully collected probably these sputa are more valuable than those obtained by saline washing aspirated from the bronchi during bronchoscopy as the material is more concentrated and many specimens can be obtained The method is of special value in the investigations of tumours that are out of vision of the bronchoscope and often the best cytological studies seem to be possible in these obscurely placed lesions The method is now far beyond

the following figures carcinoma seen at bronchoscopy 113 (82 per cent) positive biopsy 79 (57 per cent) In the 25 per cent without positive biopsies rigidity or true stenosis of the bronchus were regarded as evidence of carcinoma

the experimental and tentative stage and if used is of the greatest diagnostic value Even in 1943 Gowar could report the presence of cancer cells in the sputum in 64 3 per cent of 93 proved lung growths.

Direct lung puncture is unwise because of the dangers of bleeding and of producing pneumothorax and pleural infection in a few peripheral tumours with bony involvement the method might be justifiable Biopsy of enlarged lymph nodes in the supra-clavicular fossae and the axilla is of occasional value and may be less upsetting than a bronchoscopy in a patient who will be inoperable if the histological study of such gland biopsies is positive Skin or subcutaneous metastases can also be excised and will show the nature of the primary growth Pleural biopsy in the presence of effusion is useful (page 239)

Exploratory thoracotomy

If the clinical history and the radiological examination support a diagnosis of bronchial carcinoma, exploratory operation will be indicated, even if bronchoscopy and sputum examination have been negative , if appeal was not made to this procedure many peripheral carcinomata would miss resection in the early stages In practice few errors are made but it is often difficult to persuade a patient with a symptomless tumour, perhaps discovered on mass radiological examination, to submit to this procedure It is not always possible even at thoracotomy to be sure of the diagnosis and occasional errors will be made the use of frozen histological sections will not ensure complete accuracy but the lobectomies performed on inflammatory lesions are few and often prove to be the most efficient treatment

The operability rate. This unfortunately remains low but is improving In a recent analysis of 842 patients submitted to thoracotomy Taylor (1955) found that the growth was resected in 512 patients With greater care in the selection of patients this figure has been improved upon in 1954 in my unit, 90 patients were operated upon and the lung or lobe removed in 65 Gifford and Waddington (1957) in reporting 2,156 cancers of the lung described 464 tumour resections in 714 operations

Operability rates are not strictly comparable from different clinics in some hospitals palliative pneumonectomy is employed, when the operative findings show that " cure " is impossible because of extensive mediastinal involvement, in the hope that the last few months of life will be more tolerable if haemoptysis or septic effects from a lung grossly infected distal to a tumour are stopped When the criteria for thoracotomy are based on scrupulous pre-operative choice the resection rate is high , in the series of 681 proved cases of lung cancer at the Massachusetts General Hospital, Churchill and others carried out thoracotomy on 294 and performed lobectomy or pneumonectomy in 171, a resection rate of 58 2 per cent But the authors themselves are careful to point out that in the period under review 1,130 patients were admitted in whom a clinical diagnosis of cancer was made and that in 681 this clinical diagnosis was confirmed by actual histology, the remainder being excluded from the resection rate survey If the chest has been opened for carcinoma, however inoperable the condition is, palliative pneumonectomy carried out by section through actual tumour extension may be better than closure without resection, for not only is death accelerated by this but much misery is experienced in patients who continue to cough up blood and sputum and who have pyrexia as the result of lung infection Abbey Smith (1957) has put this opinion to the practical test in reporting that in 147 consecutive cases of lung cancer thoracotomy enabled resection to be carried out in 143, a resectability rate of 97 2 per cent All of these patients were followed up 18 of the resections were regarded entirely as palliative operations and of these 10 died post-operatively Of the

survivors the palliation achieved was confirmed by careful observation in their post-operative period

Treatment of bronchial carcinoma

Pneumonectomy or lobectomy Radical pneumonectomy is logical when the growth is confined to the lung and has not extended either directly or by metastases beyond this From an anatomical point of view the lymphatic channels of the lung are widely inter-connected and lobectomy as an operation is as apparently illogical as the excision of a cancerous segment of the breast Nevertheless there is a place for lobectomy in this disease and in recent years the number of patients submitted to this less radical procedure has increased The obvious aim at radical surgery must be modified by circumstances chiefly of a physiological nature if total lung resection will produce a respiratory cripple lobectomy is preferable With careful selection Churchill (1950) and others between 1930 and 1950 performed 57 lobectomies as against 114 pneumonectomies and the follow up results did not disclose any notable difference in results these excellent results depended on a selection which allowed lobectomy for strictly localized cancer and the operative procedure included as full a lymph node removal as possible Lobectomy was practised in patients with diminished cardiac or pulmonary reserve and when the exact diagnosis at operation remained uncertain it was used for small peripheral lesions and to provide satisfactory palliation in a patient when resection whether total or lobar could not be regarded as curative Belcher (1956) provided figures to support this

Briefly the indications for lobectomy are

1 In the elderly with poor cardio-respiratory reserve where the growth has not extended clinically beyond the lobe In such patients the slower rate of growth and a lower operative mortality rate often justifies lobectomy

2 In circular peripheral tumours without glandular involvement especially when doubt prevails as to the exact diagnosis (I have been grateful on several occasions that lobectomy was done for such categories as lobes containing hydatid cysts the peripheral type of adenoma tuberculoma and chronic lung abscess have been removed when the pre operative diagnosis was bronchial carcinoma)

Pneumonectomy however remains the obvious operation in many patients for only by this method can a radical block dissection be practised the lung glands and mediastinal areolar tissue being resected in one piece The operation can be truly radical if the intra pericardial method of Allison is practised together with a wide resection of pericardial tissue and removal of the mediastinal and tracheo bronchial lymph glands en bloc (Brock 1955)

Is excision a worth while procedure ? In all forms of cancer surgery there are inevitably waves of pessimism and optimism In cancer of the lung we cannot pretend that results are outstandingly good but resection provides incomparably better results than no treat ment or care by radiotherapy The operative mortality rate is now about 10 per cent and has fallen steadily in recent years with better anaesthesia better operative technique and advances in post-operative treatment

Several series of resections now show that following a successful resection 30 to 40 per cent of the patients are alive five years later and this figure should be widely known as it is better than many think After resection over 50 per cent of the patients are alive at the end of two years the remainder having died of metastases It is clear that once the patient has survived for two years his chance of living five years is good

Radiotherapy. The use of radium or radon which was employed previously as a palliative method to relieve the effects of bronchial obstruction has been superseded by deep X-ray therapy which often produces helpful palliation Radiotherapy may be employed as a *radical* or *palliative* procedure For radical therapy the patient must be in hospital in bed

Morrison and Deeley (1957) have recently indicated that the use of mega-voltage X-ray therapy has provided better results and less discomfort to the patient than was achieved by conventional machines

The chief indications for radiotherapy are

(1) in patients with the anaplastic type of undifferentiated growth These are often of " mediastinal type " shown to be inoperable by clinical, radiological, bronchoscopic or operative findings, (Fig 12 13)
(2) in patients with superior vena caval obstruction* or enlarged supra-clavicular glands,
(3) in the young age groups (18–30 years),
(4) as a post-operative measure when the pneumonectomy has been carried out in the presence of obvious glandular involvements,
(5) as a palliative measure for severe pain when the condition is inoperable

Some surgeons would widen these indications by advising radiotherapy for most patients with undifferentiated anaplastic tumours as revealed by bronchial biopsy and by using it post-operatively as a routine after resection

Radiotherapy should not usually be employed in old feeble patients or when severe cachexia is present, for the treatment often aggravates the asthenia and dyspnoea. it is usually inadvisable when pleural fluid or gross sepsis such as empyema or lung abscess is present Sometimes, however, a palliative course of deep X-ray therapy may unblock a main stem bronchus obstruction and lead to dramatic relief of sepsis by allowing the patient to expectorate the pent-up secretions

Radio-active gold instilled into the pleural cavity for blood-stained recurrent effusions due to proved carcinoma may be a palliative procedure of value

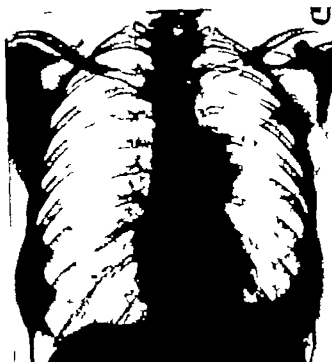
Operative procedures in pneumonectomy for bronchial carcinoma. The aim is to remove the whole lung with its associated lymphatic field as widely as possible There is considerable support today for the wider use of Allison's intrapericardial ligation of large vessels associated with removal of much of the pericardium and of the loose tissue of the mediastinum from high up in the thorax down to the diaphragm, together with a block dissection of the lymphatic glands around the main bronchus stem, in the tracheobronchial angle, and around the pulmonary artery, superior and inferior pulmonary veins This operation originally designed to extend the scope of lung excision to include cases of extra-pulmonary spread to the pericardium, can well be employed as the routine operation of total pneumonectomy and it fulfils the precepts of radical cancer surgery It has not, however, displaced entirely the use of extrapericardial dissection pneumonectomy for cancer of the lung when the growth is early without mediastinal or glandular involvement Even when the glands in the neighbourhood are extensively invaded, palliative pneumonectomy is often indicated to relieve persistent haemoptysis, expectoration of infected sputum and pyrexia, the result of lung abscess and atelectasis or bronchiectasis, distal to the growth itself Involvement of the parietal pleura and the ribs adjacent to the tumour does not

* Szur and Bromley (1956) found that of 107 patients with superior vena caval obstruction due to carcinoma 69 per cent were irradiated with the result that no further obstruction developed prior to death

necessarily preclude a satisfactory excision for the dissection may be carried into the extrafascial and the extracostal plane and include segments of the whole chest wall

The operations to be considered therefore are

A Routine dissection pneumonectomy
B Radical intrapericardial pneumonectomy
C Extrapleural pneumonectomy
D Lobectomy





(*a*) (*b*)

Fig 12 13

(*a*) Radiograph of a woman of 5* with mass adjacent to mediastinum.
At thoracotomy this tumour was inoperable with extensive invasion of the pericardium. Biopsy showed an anaplastic oat-celled carcinoma. (Radiotherapy by Dr J Bromley)

(*b*) Radiograph of the same patient three years later
The left upper lobe is atelectatic but a large amount of the ovoid mediastinal mass has disappeared. There were no symptoms and the patient is at full work six years after treatment.

Anaesthesia If the patient has much sputum the bronchus can be occluded by a Carlens tube or a Thompson blocker If bronchial occlusion is necessary (this is not common) a bronchoscope is passed and any pus seen in either bronchus is sucked out the blocker is passed below the carina into the main stem bronchus of the affected side and the balloon on its tip is inflated The bronchoscope is withdrawn leaving the blocker in place a large bore intratracheal tube (Magill) is then passed into the trachea and anaesthesia maintained by pentothal relaxants and gas and oxygen Controlled respiration undoubtedly provides a quiet operative field and prevents the build up of CO_2 tension in the blood if the carbon dioxide absorption is efficient

Position on the table This is by no means standardized there are at least three recognized positions

(1) The supine position this allows the surgeon to enter the thorax through an anteriorly placed incision (Rienhoff) It is not widely used in this country because the access to the lung hilum is inferior to that provided by the posterolateral thoracotomy

position The incision had the advantage of keeping the mediastinum more central than in the lateral approach in the early days of thoracic anaesthesia, but this can be maintained by modern controlled respiration



FIG 12 14 —Mass at hilum of left lung the left leaf of the diaphragm is raised and moved paradoxically on screening, indicating involvement of left phrenic nerve

At thoracotomy this tumour was operable by the intrapericardial method, a large portion of pericardium together with the phrenic nerve being excised



FIG 12 15 —Pneumonectomy specimen of carcinoma of lung

The tumour had involved overlying ribs, which were removed together with the lung the segment of removed chest wall is to the right

(2) The normal classical posterolateral thoracotomy incision

(3) The head-down position for a posterior approach (the Overholt or Holmes Sellors position) This position enables the secretions from the bronchi to flow out by gravity

through a large intratracheal tube which has a special trap to collect them. It also prevents the falling away of the mediastinum towards the lower non-operated side that is sometimes seen in the lateral thoracotomy

The operation of pneumonectomy through a posterolateral thoracotomy A long curved incision starting halfway between the medial edge of the scapula and the second thoracic spinous process sweeps downwards and medially to pass below the angle of the scapula to the front end of the fifth rib the incision is deepened to the fascia overlying the rhomboid muscles and the trapezius bleeding points in the skin are seized with artery forceps which are then touched with diathermy coagulation With the scalpel the auscultatory triangle is opened and then the muscles are divided up to the second thoracic spinous process level and forward to the costal cartilage with the cutting diathermy point after skin towels have been affixed to the skin edges Several large vessels require ligation with silk or thread the remaining bleeding points being sealed by diathermy coagulation After this wide muscular division, the scapula is lifted off the chest wall by a scapula retractor and the second rib is identified to enable the operator to count down from this to the fifth or sixth either of which can be selected for resection the periosteum of the rib is divided from the transverse process of the thoracic vertebra to the costal cartilage in front and is elevated from the rib by a combination of rib periosteal rugine and Doyen s raspatory The rib is resected from the transverse process to the costal cartilage the section being effected by Tudor Edwards s costotome or Bethune s rib shears The pleural cavity is opened by an incision through the posterior bed of the periosteum and the parietal pleura this incision is made cautiously in case the underlying lung is adherent if no adhesions are present the chest is spread widely by a rib spreader of the Finochietto or Price Thomas type (see Fig 4 7) If the lung is adherent it must be separated by a combination of scalpel or scissor dissection this is greatly facilitated by having a chest light in the thorax and holding it behind the adhesions to be sectioned if the adhesion is dense it is often wise to strip the adherent lung in the extrapleural plane over the area of fixation As soon as the chest is opened widely the question of operability is assessed the hilum cannot be properly inspected until the apex of the lung has been held down in a moist saline swab so that on the left side the aortic arch is clearly seen and on the right the azygos vein beneath these two structures the state of the upper hilum area can be inspected by sight and palpation Mediastinal invasion does not preclude resection for the pericardium can be opened widely and an estimate made of the possibility of ligation of the pulmonary arteries and veins nor does involvement of the tracheo-bronchial or other mediastinal glands prohibit resection for these may often be removed *en bloc* with the lung Before commencing the resection it is important to make sure that the inferior pulmonary vein can be isolated either within or without the pericardium If the vein is invaded the left atrium is held in a clamp and later sectioned and closed

If the case is operable and there are no mediastinal extensions an extrapericardial resection may be proceeded with

Should the pulmonary artery the pulmonary vein or the main bronchus be secured first? The early exposure and temporary clamping of the bronchus has the undoubted advantage of minimizing any risk of bronchial secretions spilling over from the affected side into the underneath sound lung or of causing blockage of the anaesthetic airway If however there is heavy involvement by growth of the glands and the pulmonary artery or veins it is often necessary for these to be secured through a wide pericardial incision before the bronchus can be isolated and clamped above the tumour formation

Because of the danger of tumour masses being displaced into the pulmonary vein draining

the affected lobe or of metastatic fragments being swept on into the circulation, Allison has advocated the ligation of the vein as the first step in the operation

But each operation must be planned according to the existent conditions and if there is a danger of the infected bronchial secretions being spilt over into the sound side the bronchus should be secured at the first stage of the intrapleural procedure It may be said here that the face-down position of Overholt or Sellors facilitates access to the bronchus whereas the dorsal position associated with an anterior approach makes the early definition of the bronchus more difficult

The isolation and division of the pulmonary artery This is easier on the left than the right side because of the greater length of the vessel and because there is no overlapping superior vena cava

The left-sided ligation With the apex of the lung held well down in a moist saline swab, the mediastinal pleura lateral to the phrenic nerve is opened widely over the whole lung hilum so that the pulmonary artery and the superior pulmonary vein are well seen, at the upper end of the mediastinal incision the line of exposure curves outwards over the aortic arch and then behind the hilum so that the main bronchus is exposed behind the anteriorly placed main pulmonary arterial stem The loose areolar tissue and the lymphatic glands in this area are freely dissected by scissors and displaced downwards to be removed later en bloc with the lung Careful attention to haemostasis is necessary throughout this procedure and the systemic blood vessels which supply the glands are sealed by diathermy Many strands of the anterior pulmonary nervous plexus require division before the true sheath of the pulmonary artery is seen and opened between the pulmonary artery and the superior vein there is a pericardial extension of dense tissue which is carefully divided, it is the fold over the obliterated vestigial vein of Marshall The sheath of the artery is thoroughly cleared of areolar tissue within its sheath by a combination of fine scissor and pledglet dissection before a curved blunt-pointed forceps of the Moynihan cholecystectomy type is slowly and deliberately insinuated behind the vessel The whole aim is to clear the vessel thoroughly, as a clumsy premature attempt to pass the forceps before this has been done may tear the posterior wall of the vessel If there is cancerous invasion of tissue in this area intrapericardial securing of the artery is indicated

A strong thread ligature or silk ligature mounted on long forceps is held down to the open jaws of the forceps and brought round the vessel and securely tied as medially as possible (Fig. 12 16 (*a*)). This manœuvre is repeated and a second ligature tied as laterally on the lung end of the cleared vessel as possible Before division of the vessel it is wise to transfix the artery with a fine thread ligature on a needle for additional security, the artery is then divided

The right-sided artery The mediastinal pleura is widely opened, as on the left side, close to the anterior border of the superior vena cava which is then retracted medially by the use of two curved forceps holding pledglets As the stem of the right pulmonary artery appears shorter because of the overlap of the superior vena cava this mobilization of the great vein exposes a reasonable length of artery, division and ligation of the azygos vein is a help The two main branches of the artery may be secured laterally and separately so that after their division longer lengths of the proximal stumps of these vessels are left on the mediastinal end of the divided artery

The superior pulmonary vein This is dealt with either at this stage or after the bronchus has been secured On the right side the upper branch of the vein usually overlies the artery and is separated from it by a marked fibrous pericardial extension which requires division, it is often helpful to secure and divide this branch before the main artery is exposed.

The superior pulmonary vein is dealt with in the same way as the artery and the ligature on the mediastinal end may be supplemented by a transfixion stitch placed more laterally before the vein is actually divided

The bronchus The loose tissue parts of the posterior pulmonary plexus and the glands

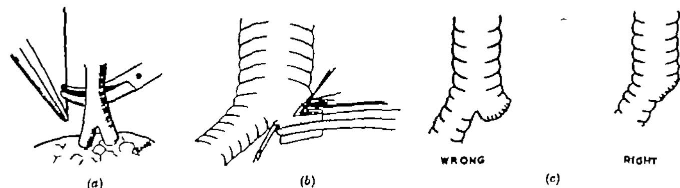


Fig 12 16—Diagrams of pneumonectomy

( ) Ligature being held down to forceps behind the artery
(b) Division of bronchus and start of suture.
( ) Bronchus sutured.

around the main stem bronchus are cleared by scissor and pledglet dissection the wall of the bronchus on all aspects should be cleared thoroughly before curved forceps are passed behind it The bronchus should be cleared right up to the carina and this involves a deliberate exposure of the lateral wall of the trachea * The bronchus must be divided close to the trachea so that no avascular blind stump is left if an undue length of bronchus is left a bronchial stump fistula is more likely to develop than if it is divided close to the trachea attention to this point encourages sound bronchial healing more than the choice of method of bronchial closure or the adoption of special suture material A sutured bronchial stump that is flush with the trachea falls away into the loose tissue of the mediastinum where it rapidly acquires a local investment of surrounding adventitious tissue (see Fig 12 16)

Should the bronchus be sutured behind a clamp or should an ' open bronchus be closed ? The many published methods of the technical closure of the bronchus indicate that no single perfect technique has been elaborated the high division of the bronchus is probably the most important point in avoiding fistulous formation. If the bronchus is held in crushing clamps and divided between them the devitalized tissue in the upper clamp is in a poor condition to hold sutures single or continuous passed through its wall above the clamp If only one clamp is employed and the bronchus is deliberately opened above it interrupted sutures can be placed through the cut open end as the division proceeds and this does not impair the vitality of the tissue so much as when the sutures are passed above a clamp (Fig 12 15 (*b*)) The disadvantages are that the anaesthetic gases may escape through the open bronchus with some temporary uneasiness and blood may enter the open bronchus but both of these can be controlled readily

The bronchial blood vessels should not be damaged beyond the line of section This advice though good is not always possible to follow in total pneumonectomy for cancer when the removal of the glands above the point of section often involves damage to the main bronchial vessels The object always should be to suture a stump that is viable the open bronchus technique should be used so that no crushed dead tissue is included in the sutures which should be of interrupted non absorbable material (90 thread, 00 silk or

* An infiltrated portion of the trachea may have to be resected and repaired by a dermal graft often reinforced with 25-gauge silver wire (the Gebauer graft)

stainless steel) As far as possible the sutures should be so placed as to neutralize the bow action of the cartilaginous rim which keeps the rim patent the suture should bring the membranous part to the concavity of the cartilage rim Many surgeons resect the last cartilaginous ring but in this procedure there is considerable risk of making the remaining cuff of tissue avascular and damaged

The reinforcement of the bronchial suture line Many attempts have been made to reinforce the line by using local mediastinal tissue, by the fashioning of an intercostal bundle with its underlying pleura which is then sutured to the bronchus or by the use of a large pedicled pleural flap or one fashioned from pericardium On the left side the pleural flap is dissected off the chest wall over a wide area, the upper limits being well above the aortic arch and the lower limit being to the sixth rib A square of pleural membrane with its base attached over the aorta is turned down on to the bronchial stump three sutures that have been passed through the bronchus stump and were left uncut after the closure had been completed have both ends re-threaded on to small curved needles and are passed through the flap in appropriate sites so that when tied they hold the endothelial surface of the flap snugly on to the bronchus, which has been covered with penicillin powder The flap is then loosely attached at its periphery by a few fine sutures to the surrounding mediastinal tissue, all " tenting " being avoided

On the right side the flap is dissected well above the azygos vein

The inferior pulmonary vein It is often easier to expose this from the posterior aspect The lung is held upwards and medially and is kept on the stretch while the pleura is opened widely from the lower end of the previous incision into it made to expose the bronchus, to well beyond the lower border of the vein which is readily seen at the upper end of the ligamentum latum pulmonis The loose areolar tissue around the vein is cleared and its proper sheath opened before the ligature is passed round it After this vessel has been divided the lung is free except for its attachment to the ligamentum latum which is then divided close to the mediastinum the ligament always contains vessels which require clamping and ligation As much tissue as possible is removed as there are always lymphatic glands present especially in the region of the inferior pulmonary vein

The completion of the operation The phrenic nerve is isolated as it lies on the pericardium and a segment of it removed Price Thomas does not divide the phrenic on the left side because of the risks of gastric disturbances that may follow in some patients Ligatures are required on both ends to secure the accompanying blood vessels After haemostasis has been established the chest is closed in layers without drainage, penicillin powder or liquid being left in the pleural space The intrapleural pressures are adjusted to normal with an artificial pneumothorax apparatus with the patient in the supine position

Should the pleural cavity be drained ? Some surgeons employ closed intercostal drainage for 24 hours but this is not essential The intrapleural pressures are more easily adjusted if there is no drainage tube, the risk of infection via the tube track is abolished and the patient is more comfortable in bed In addition an " air cushion " is provided to support the bronchial stump during coughing Even if a tube is used fluid accumulates later in the chest and there is no evidence that less post-operative aspirations are needed in the drained than the undrained cases

Intrapericardial ligation of the great vessels in pneumonectomy.* This procedure was first introduced by Allison (1946) to extend the scope of the operation to include

* Brock and Whytehead (1955) have published a full description of a really radical pneumonectomy whereby the lung, its fascial connections and lymphatic drainage are removed en bloc. Since 1947,

patients in whom mediastinal extension of the tumour made an extrapericardial operation impossible It is now advocated by many thoracic surgeons as being the logical operation in pneumonectomy for cancer because it provides a wide excision of the surrounding tissue and lymphatic fields and enables a more radical operation to be performed It is however followed by a higher incidence of post-operative cardiac irregularities

The operation The main thoracotomy approach is as described on page 271 The pericardium must be freely opened once the decision to use the intrapericardial technique has been made The sac is opened just in front of the phrenic nerve which is then divided the pericardium must be freely opened around the whole lung root both anteriorly and posteriorly As the superior pulmonary vein often overlaps the artery it may be secured tied and divided before the artery is dealt with the serous reflections that provide a type of mesentery to the vessel require division before the vessel can be safely encircled a transfixion stitch may be used distal to the first ligature tied near to the auricle The pulmonary artery is then cleared after division of the serous reflection on its postero-inferior surface the vessel is divided between ligatures with the added safety again of a trans fixion stitch The inferior pulmonary vein is then isolated ligated and divided

On the right side the parietal pericardium forms a bed between the superior vena cava and the right pulmonary artery and in this angle the serous pericardium is reflected on to the under-surface of the artery (Allison) When these two layers have been cut the artery can be isolated in the recess behind the superior vena cava and tied and divided Before these pericardial folds have been divided the artery lies in a triangular depression of which the medial and inferior borders are formed by the superior vena cava and the superior pulmonary vein (post-caval recess of Allison)

After the vessels have been dealt with the pericardium over the main bronchus is opened and the bronchus exposed and treated as in the operation of extrapericardial pneumonectomy The pericardium at the back of the lung root is then incised and the lung with the lymphatic glands from the tracheo bronchial angle with much loose mediastinal tissue and a considerable portion of pericardium removed *en bloc*

With this approach it is possible to remove a portion of the wall of the auricle in those patients in whom cancerous growth has invaded the pulmonary veins

The post-operative care of pneumonectomy has been discussed in Chapter 5 and the diagnosis and treatment of the complications outlined

Lobectomy The operative plan is as described on page 169 in the treatment of bronchiectasis with the exception that all the neighbourhood lymphatic glands are removed

Thoracic adjustments and lung function after pneumonectomy After total excision of one lung the remaining lung enlarges and unless active measures are adopted to prevent it the mediastinum is pushed over to the other hemithorax the ribs of which progressively fall inwards and become approximated with consequent diminution in the size of that side of the chest In time the pleural cavity on the pneumonectomy side becomes completely obliterated the process being aided by the elevation of the diaphragm and the organization of the pleural fluid into dense fibrous tissue (Fig 12 17)

That this natural process of obliteration of the dead space is not altogether satisfactory is generally accepted and constant efforts have been made to overcome the disadvantages the chief of which are the great tendency for the remaining lung to over-distend and for the mediastinum to become grossly distorted

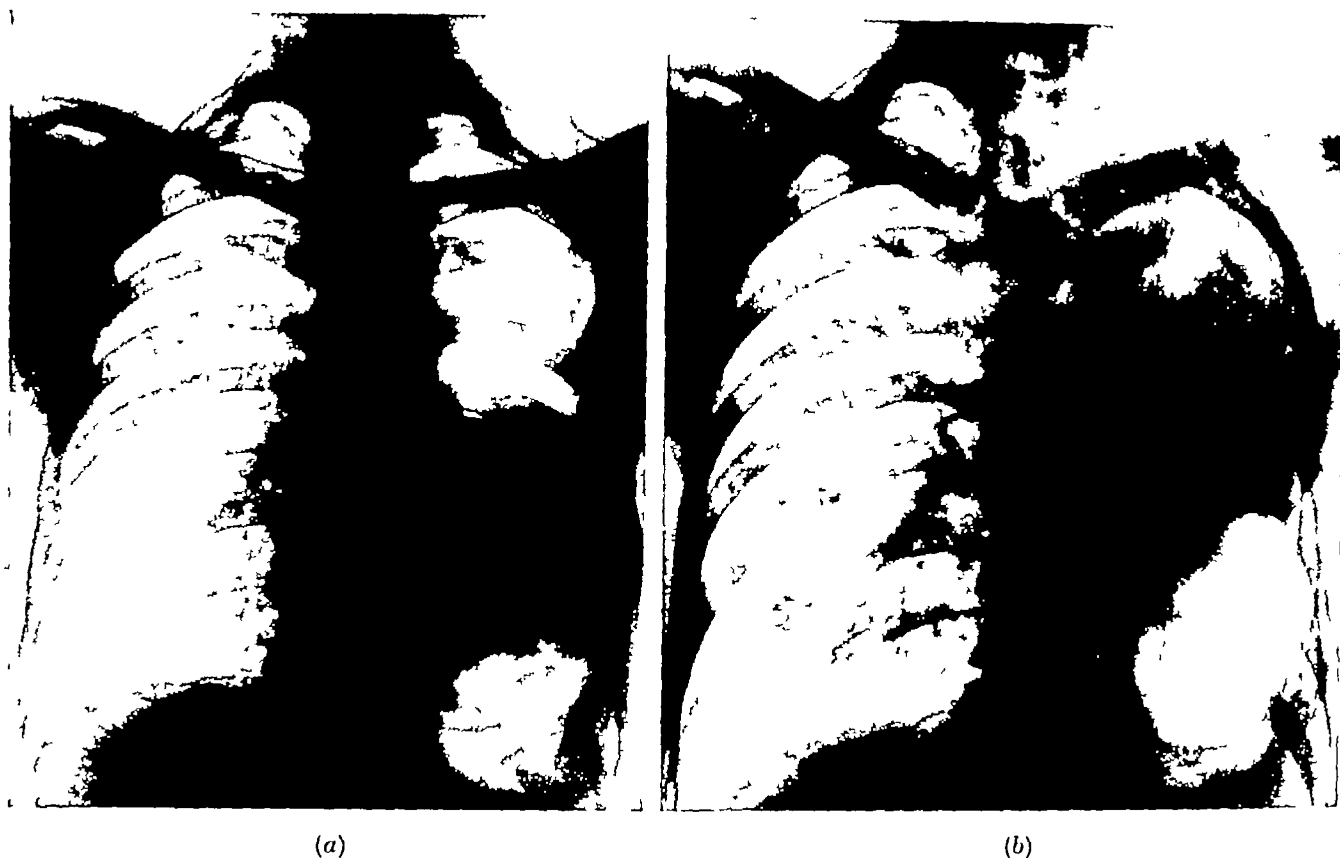
145 radical operations as against 49 simple pneumonectomies were done 72 (50 per cent) of the radical cases were alive as against 9 (18 per cent) of the simple pneumonectomy group

The methods adopted to prevent these two developments are

(*a*) Thoracoplasty

(*b*) The use of artificial pleural fillings (plasma, polythene balls and packs)

(*c*) Pneumo-peritoneum



(*a*) (*b*)

FIG 12 17

(*a*) The radiographic appearances of the chest a week after left pneumonectomy
The mediastinum is kept central by the artificial introduction of air into the pleural space

(*b*) A year after left pneumonectomy
The right lung has distended to push the mediastinum over to the left side this displacement, together with the elevation of the left leaf of the diaphragm and the formation of a fibro thorax, has obliterated the left pleural space

Of these methods the most satisfactory would appear to be thoracoplasty, but it is not certain that this added operative burden helps a patient, often elderly, who has successfully undergone the operation of pneumonectomy It is therefore appropriate at this stage to discuss the physiological changes that follow lung excision

Functional adaptation after pneumonectomy. A clinical study of pneumonectomy patients in the immediate post-operative periods and at subsequent follow-up, usually at three-monthly intervals, is the basis for the following points

(*a*) Immediately following operation the respiratory rate increases moderately but rarely exceeds 25 per minute , this rarely persists longer than from three to five days and then settles around 20 a minute

(*b*) There is a slight increase in the depth of respiration

(*c*) In some 15 to 20 per cent of adults cardiac abnormalities of rhythm develop, often associated with transient pulmonary oedema, which settles satisfactorily in most patients

(*d*) Functional activity is restricted, on the average proportional to the age of the patient children being the least affected Life is, however, usually compatible with sedentary occupations and moderate degrees of exercise, such as walking two to five miles

"at their own pace" Children show little limitation in their activities and are usually able to attend school and play games with their contemporaries

(e) Vital capacities measured at intervals after pneumonectomy for carcinoma vary on an average between 1 500 and 2 000 c c and these are helpful as a rough guide to the amount of activity that is tolerated and their subjective symptoms such as dyspnoea

Respiratory physiologists have investigated limited series of patients and their findings provide the scientific explanations for the above clinical observations

1 *The minute volume respiration* is not significantly changed being compensated for by a slight increase in rate and depth

2 *The oxygen uptake* naturally must remain approximately the same so that the remaining lung increases its uptake inversely proportional to the percentage of the total oxygen provided by that lung pre-operatively

3 *The maximum breathing capacity* is reduced but much less than might be expected it may be as much as 80 per cent of the pre-operative value explicable by the good functional co-ordination of the respiratory muscles and the increase in rate of respiration which compensates for the loss in depth

4 *Decrease in the respiratory reserve* naturally results because of the loss in maximum breathing capacity

5 *Gas mixing is improved* because of the increase in ratio of effective tidal air to functional residual air

6 *The total lung volume* in deep inspiration is greater than an homologous normal lung explained by the absence of the opposite lung with a mobile mediastinum

7 *The pulmonary blood flow* must be doubled after pneumonectomy and is accomplished by an increase in the rate of flow or an increase in the functional capillary bed or both

8 *Pulmonary blood pressure* Cournand has demonstrated that in the course of strenuous activity very marked pulmonary hypertension occurs Theoretically this seems an excellent reason for purposely limiting activity after pneumonectomy but he states that electrocardiographic studies after several years do not reveal evidence of right ventricular hypertrophy

Finally the thoracic surgeon s main interest is centred around the possible development of true emphysema or increasing distension of the lung in full expiration and its prevention by thoracoplasty on the pneumonectomy side The answer is not available at the moment but over-distension is not inevitable in the absence of thoracoplasty but is probably related to persisting pathological changes Peters *et al* in an investigation of a small series of children after pneumonectomy found a high residual air in 50 per cent of his cases but still with a good exercise tolerance It would seem right to recommend thoracoplasty in non tuberculous cases only where there is evidence of increasing residual air and a reduction in the maximum breathing capacity

An interesting and important remark by Peters was that his two best results were in a gymnast and a construction worker both of whom had made whole-hearted efforts to overcome their respiratory handicap by physical training to increase the maximum mobility of the chest wall diaphragm and mediastinum A further example of this has occurred in our experience where a professional sprinter after pneumonectomy was able to run a hundred yards in 11 seconds

Post-pneumonectomy emphysema It is strange after so many years in which lobectomy and pneumonectomy have been carried out that doubt still exists as to whether the remaining lung tissue becomes truly emphysematous (i e with rupture and atrophy of alveoli and loss of elastic tissue) or whether the condition is one of simple lung distension

even with true hyperplasia In young children who have undergone pneumonectc bronchiectasis it is possible to imagine that hyperplasia and hypertrophy have follow in adults and especially in the older subjects who have had excision for cancer it is to conceive of this happening and the remaining lung distends and become emphysematous

Many investigations have been done to attempt a physiological assay of the in respiratory function and especially to try to establish whether these changes are order that would be expected in emphysema (Cournand and Berry, 1942, Birath 1947)

The effect of age As would be expected the resilient and actively growing ti young subjects enables extensive resection of lung tissue to be executed withou measurable disturbance of cardio-respiratory function, and this can be noted both in ments on young animals and in young children, but in older patients there is a consi reduction in breathing reserve, especially with increased activity The maximum br capacity is diminished, not in proportion to the diminution in lung volume so mucl alteration in the state of the remaining lung (Cournand and Berry, 1942) The ren lung loses efficiency if it becomes over-distended Cournand showed that thoracopl the pneumonectomy side could largely prevent this over-distension of the "good But before adopting the principle that thoracoplasty should be used to obliterate the pleural space or pneumonectomy gap in patients who have undergone this operati important to point out that clinically many hundreds of these patients have lived comf lives for many years without dyspnoea except on rather severe exercise and that a physiological examination of this type of patient (Birath and Crafoord, 1947) has that the expected disagreeable effects are not so severe as would be expected They their findings on patients two to twelve years after operation by investigating th lung volume and its fractions, the estimation of the efficiency of the ventilati reference to the respiratory dead space, by a determination of the blood gases and by clinical findings The lung ventilation was obviously worsened with an absolut relative increase in the respiratory dead space due largely to the increased lung in and possibly to emphysema, but dyspnoea, though present immediately after ope steadily diminished later and they feel that even if emphysema develops slowly it encr very little on function.

In this country thoracoplasty is not used widely as a method of obliterati pneumonectomy gap after operations for cancer, but is frequently employed after lung excision in cases of pulmonary tuberculosis where it is undesirable to allow the " side which has usually been the site of tuberculous infection, to over-distend

The use of artificial pleural fillings Certain plastic materials such as polythen been used to fill in the pleural space after pneumonectomy they are not irritant tissue and slowly become encapsulated in thin fibrous tissue Surgical reluctance foreign bodies has, however, restricted their use except in a few clinics and private con tions not infrequently elicit a story of mishaps usually associated with infection and disruption

Phrenic paralysis and pneumo-peritoneum After pneumonectomy it is cust to resect a portion of the phrenic nerve in the thorax before closing the chest and the quent elevation of the diaphragm assists in decreasing the size of the space The r the paralysed leaf may be accentuated by the use of a pneumo-peritoneum (Fig 1 This method has not gained great popularity but is of considerable value when thoroughly if the diaphragm is to be elevated to a high level it is important to sta

pneumo-peritoneum early after operation before it becomes fixed by organization of the inevitable overlying haemothorax



Fig 12 18 —Left post-pneumonectomy space after phrenic nerve paralysis and pneumo-peritoneum, three months after operation

PRIMARY MALIGNANT TUMOURS OF THE LUNG OTHER THAN CARCINOMA

The rarity of malignant tumours of connective tissue origin justifies the briefest mention of them however interesting the individual case may be Fibro-sarcoma is occasionally encountered Ball (1931) found 13 examples in the literature from 1900 to 1931 These tumours as in sarcoma elsewhere may be small round-celled large round-celled or spindle-celled sarcoma and a slow growing type of fibro-sarcoma exists which may be seen developing in the bronchus more commonly or in the lung parenchyma Carswell and Krafft (1950) in reporting a patient with a fibro sarcoma of the bronchus treated by pneumonectomy stated that 31 examples of primary sarcoma of the lung had been reported in the American literature and that there were only 6 described as being primary in the bronchus In the same year Black (1950) and Curry and Fuchs (1950) each described a bronchial fibro-sarcoma. Curry and Fuchs patient actually expectorated the tumour She was a girl of 13 who was well four years after this incident An instance of a malignant myo-sarcoma is given in Fig 12 22 and a sarcoma of lung in Fig 12 21

Tumours of the trachea and carina

Respiratory obstruction with stridor and often haemoptysis calls for an endoscopic examination; a previous examination by tomography may indicate the extent of the tumour encroachment on the tracheal lumen Carcinoma, primary or as an extension from the thyroid or oesophagus, adenoma, polypus, lipoma or fibroma may be the cause of the symptoms, carcinoma being the most common (Ellman and Whittaker, 1947) Upward extension of a bronchial carcinoma may require excision of some of the trachea as part of the radical excision Endoscopic removal has not been satisfactory and the cervical and thoracic trachea can be partially excised with restoration of a good airway by the use of fascia lata incorporated in stainless steel wire (Belsey, 1946, 1950) or tantulum gauze (Rob and Bateman, 1949) Dermal grafts in which are incorporated silver wire sutures (26 to 28 gauge) may be used instead of fascia lata (Gebauer, 1951) The tumour most suited for excision is the "adenoma", this mixed cell tumour behaves like the adenoma of the bronchus but has more pronounced malignant tendencies It is sometimes regarded as a "cylindroma" and occurs most commonly in the lower half of the trachea and spreads along one or both main bronchi It is important to decide at endoscopy which bronchus is involved when the extension is in that plane as the exposure can be made through either thoracic cavity, it may be necessary to remove one lung together with the affected area of the trachea All arrangements must be made to carry on one lung anaesthesia in these patients If the tumour has not extended to the main bronchi, the right-sided approach is undoubtedly the best If the left side is used the aorta is fully mobilized and can be temporarily retracted by the use of linen tapes during part of the procedure This approach is simpler than might be imagined and my colleague, Leigh Collis, and myself have both used it Reconstruction is only possible if one recurrent laryngeal nerve and one superior laryngeal nerve can be preserved so that respiratory obstruction, the result of bilateral cord paralysis, and the loss of sensory fibres (which would be followed by food inhalation into the air passages) is avoided In addition to closed water-sealed drainage, tracheotomy may be indicated to relieve the stress of cough on the graft and to facilitate bronchial suction Abbott (1955) has published a valuable paper on the technical problems involved, and Barclay, McSwan and Welsh [1957] have reconstructed the trachea without grafts

Benign and border-line tumours of the lung

The classification of innocent lung tumours remains unsatisfactory because many reported "tumours" are in fact examples of masses of tissue, developmental in origin and giving rise to formations of epithelial and mesodermal cells These are frequently grouped together under the clumsy and misleading term of "hamartoma" Such malformations include the arterio-venous fistula of the lung (pulmonary telangiectasis, haemangioma of the lung—see p. 25) and possibly the condition of "chondroma", pulmonary haemangio-fibroma, haemangio-endothelioma (Tudor Edwards and Brian Taylor, 1938) *

In six patients under my care from whom "chondromata" were resected, epithelial and cartilaginous tissue were present and Brewer and Brookes (1953) described them as "adeno-chondroma"

Hamartoma. These "tumours" are usually sited in the lung parenchyma and do not form really circular masses as their edges are often irregular, hence their confusion with infiltrating peripheral carcinoma on radiological appearances They consist usually of all elements of the bronchus with cartilage, muscle and epithelial elements Frequently they contain cystic spaces and the cartilaginous portion may ossify or calcify Quite exceptionally a mass of cartilage cells may project into the lumen of a bronchus and be seen and removed at bronchoscopy such endobronchial tumours may well be examples of true chondroma

The peripheral hamartoma may cause symptoms by obstructing a bronchus the last one I removed lay in the right main fissure and had produced atelectasis of the right middle

* Pleural mesothelioma or endothelioma may arise from the parietal or visceral layer of the membrane

lobe the presenting symptom being haemoptysis The particular lobectomy done was difficult technically because of the mass that overlay the hilar vessels this was removed

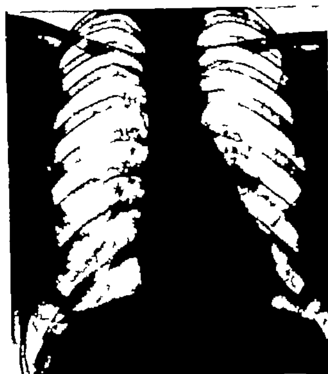


FIG 12 19 —Mass radiography of symptomless tumour near left hilum.

Female aged 4 At thoracotomy the mass lay in the main fissure, from which it was dissected free Histological examination revealed typical thymus tissue

under the impression that it was a large lymphatic gland but subsequent histology disclosed a hamartoma

A simple example of the difficulties may be instanced

Miss M aged 24 had no symptoms the tumour shown on the radiograph in Fig 12 19 was disclosed by mass radiography It was impossible to make an exact pre-operative diagnosis thoracotomy was employed and a tumour resected from the main left fissure The histological examination of the mass revealed normal thymic tissue the result presumably of an aberration of development She remains well and symptomless five years after the resection The indications for exploratory operation in symptomless lung tumours will be discussed later

Other innocent tumours Apart from hamartomatous formation lipoma fibroma neuro-fibroma xanthoma and myoma have been described an unusual leiomyoma of the left main bronchus causing atelectasis of the left lung has been reported by Turkington *et al* (1950) the patient a woman of 57 remained well after a left pneumonectomy I have done a left lower lobectomy for a similar tumour (Fig 12 20)

The exact diagnosis of many innocent tumours remains obscure until they have been removed at operation the discovery of a circular possibly lobulated tumour often symptomless by routine radiography or by the mass miniature radiography method creates at once a feeling of diagnostic uncertainty Because such tumours may be malignant bronchial growths (Figs 12 21 and 12 22) the general opinion is that excision should be practised and the disadvantages of resecting what may be an innocent condition are much outweighed by the fact that many of these circular shadows owe indeed their presence to a malignant tumour It is however important not to resect a whole lung for a simple



FIG 12 20 —Left lower lobectomy specimen removed from a man of 32

The only symptom was haemoptysis A radiograph showed segmental collapse of the left posterior basal segment The tumour was seen easily at bronchoscopy Pathological report by Professor Orr described a leiomyoma

The tumour is seen arising from the bronchial wall just below the origin of the segmental bronchus to the "dorsal lobe" (apical segment of lower lobe)



FIG 12 21 —Fibrosarcoma involving upper lobe of lung

(Photograph by courtesy of Dr Cruickshank)



FIG 12 22 —Radiograph showing a tumour of the left lung in a man of 62

This was regarded as a peripheral carcinoma After resection by lobectomy this tumour histologically was a myoma with sarcomatous degeneration, and the tumour had invaded the surrounding lung tissue

tumour such as a hamartoma the decision to employ a lobar or even a segmental resection instead of pneumonectomy may well depend on a frozen section biopsy done at the time of operation If doubt still exists and the surgical opinion is that the condition is innocent the lesser resection should always be practised for there is evidence that lobectomy for peripheral malignant tumours may be as effective as pneumonectomy

Bronchial adenoma Of all lung neoplasms adenoma provides about 4 per cent they present striking differences from bronchiogenic carcinoma and it is increasingly difficult to accept Womack and Graham's thesis that they are all malignant tumours The main objection to their classification as malignant tumours rests on their clinical behaviour rather than on their microscopical appearance They develop in a younger age group often in the late 20's affecting women more commonly than men in sharp distinction to bronchial carcinoma and are associated with a long survival even in the absence of effective treatment

At the same time it is not altogether reasonable to classify as innocent a tumour which occasionally passes beyond the normal barriers of restriction and becomes locally invasive or even infiltrates lymphatic glands to behave much as certain mixed salivary tumours do It develops presumably from the mucous glands of the bronchus and not from the surface layer of mucous membrane It causes serious symptoms and often prolonged illness chiefly the result of bronchial obstruction though it may become a large tumour when growing out into the periphery of the lung before causing serious effects

Foster-Carter (1941) reported 70 examples of whom 62 per cent were in women and in the whole series a long survival was the rule in the presence of what might now be considered inadequate treatment In my own small series with Brian Taylor there have been 19 of whom 10 were women and the average age was 30 one of these patients survived for 30 years after the initial haemoptysis at the age of 21 and in whom no more radical treatment than diathermy and radon seed implants had been employed In this group of 19 patients 9 have been subjected to what we consider adequate surgery the latest was operated upon 5 years ago and all except one are surviving—a picture very different from that seen after resection for bronchial carcinoma *

Exceptionally invasive tendencies are present and local lymphatic glands may be involved as in the only case of bronchial fistula that developed in our series of 9 resections There are records in the literature of one or two patients in whom adenomatous deposits have been found as liver metastases but on the grounds of these exceptional patients it hardly seems fair to incriminate the larger group as carcinoma as this assumption would suggest that all these patients should be subjected to radical pneumonectomy with unjustifiable sacrifice of functioning lung tissue The invasive tendency in some of the tumours has been stressed by Womack and Graham (1938 and 1942) and Adams *et al* (1942)

Pathological features The tumour most commonly arises in a main or lobar bronchus † It is a well-defined lobulated mass usually varying from 1–5 cm in diameter attached by a broad base to the bronchial wall Although commonly described as having a larger extrabronchial than intrabronchial formation a careful examination of the tumour usually shows a thinned-out shell of cartilage over the periphery of the mass that projects into

* T help me against criticism of my view that these tumours are usually benign, I can quote Price Thomas (1954) who found unmistakable malignant change in only one of his 41 adenomata Undoubtedly the "cylindroma" type of tumour typically seen in the trachea and at the carina has malignant characteristics. It does arise in the lung and behave malignantly

† A few recorded cases have established that the tumour may arise in the trachea or even involve both main bronchi (see page 280)

the lung parenchyma (Fig 12 24) The portion that projects into the lung tissue is, however, almost invariably larger than that seen in the bronchial lumen When viewed bronchoscopically the tumour may be red and vascular

Occasionally the tumour may be a large mass in the periphery of the lung, having arisen from a smaller bronchus

Histology The cells are regular in appearance, often with a well-defined tubular



Fig 12 23 —Biopsy of bronchial adenoma from patient known to have the tumour for 30 years

Note the intact mucous membrane overlying the masses of tumour cells at the right-hand side of the section



Fig 12 24 —Right lower lobectomy specimen

Adenoma arising from the segmental bronchus to the apex of the lobe The main lower lobe bronchus is compressed the main mass of the tumour projects into the lung tissue but is actually separated from it by a false capsule formed of a rim of compressed cartilage The main symptoms were haemoptysis and pyrexia Tumour 8 cm wide (Dr A M Nussey's patient)

formation, the appearance is one of great cellularity The interpretation of the section is not easy and the arrangement of the cells may be quite disorderly Very great experience is necessary before a histological diagnosis of " adenoma " can be made (Rabin and Neuhof, 1949) There is often evidence of mucous secretion and this supports the theory that the tumour develops from bronchial mucous glands, this is further suggested by the noted comparison with the mixed salivary tumour, in this suggested similarity the common features of mucoid material and of cartilage are also stressed The tumour is invariably covered by normal bronchial mucosa, which adds further to the impression that it arises from the submucosal area and not the bronchial lining mucosa (see Fig 12 23) Local metastasis to a lymph gland is unusual but does happen in a few exceptional cases metastases have been found in the liver

Clinical features Although haemoptysis is the earliest and most prominent feature, the frequent complaint of the expectoration of purulent sputum and of pyrexia indicates that the bronchial obstruction produced by these tumours causes infection in the collapsed bronchiectasis beyond the obstruction Most of the patients seen in a thoracic clinic have



(a)



(b)

Fig 12 25

(a) Woman of 30 Peripheral type of bronchial adenoma Symptomless.
At this time thoracotomy was refused by the patient.

(b) 11 months later
Patient ill, pyrexial and toxic. The left upper lobe has collapsed.



Fig 1 ?5 (c)—Tumour after upper lobectomy
The ma is partly cystic it remains well encapsulated and the histology I that of "bronchial adenoma length 13 cm.
Patient well and symptomless six years after lobectomy

atelectasis (Fig 12 27), and a few have lung abscess Before the widespread use of bronchoscopy a number of the patients had spent long fruitless days in a sanatorium in spite of a persistently negative sputum When the lobe collapses a sudden pyrexial illness may develop and be treated as pneumonia with relief of symptoms as the result of antibiotic



FIG 12 26—Male, aged 30 Large tumour (15 cm) in right upper lobe with an intrabronchial projection easily seen at bronchoscopy

The tumour has eroded rather than infiltrated the bronchial wall and the lung parenchyma A circular tumour was noted on the radiograph five years before this was removed by operation a year and a half before operation he started to have small haemoptyses There were no glandular invasions Prof J W Orr kindly examined this tumour, and from the histological appearances reported it to be a mucous secreting adeno carcinoma clearly resembling a salivary tumour type the tumour alveoli consist partly of tubules containing mucus and partly of cribriform structure Although the tumour is so circumscribed to the naked eye there is a diffuse infiltrative edge microscopically and I think one must regard this as a malignant tumour" Patient alive and well five years later

therapy In such patients the clinical and radiological detection will lead to bronchoscopy or bronchography and the cause of the obstruction will soon be clear

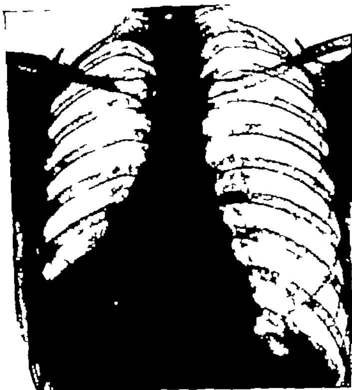
Haemoptysis without radiological features may be present and only bronchoscopy will reveal the true nature of the disease

Mrs R, a woman of 40, had suffered from repeated haemoptysis for two years the radiograph was normal Bronchoscopy revealed a tumour involving the left main stem bronchus This was treated by excision of the main stem bronchus followed by end to end anastomosis (Fig 12 28)

A mass may be found in the chest on routine radiological or miniature mass radiography without haemoptysis, though cough is a common feature

Bronchography The detection of bronchial tumours by lipiodol bronchography is not often employed, as bronchoscopy gives an opportunity to examine the tumour and perform a biopsy the tumour, however, may be demonstrated as the cause of a bronchial obstruction by bronchography If it projects into the lumen of the bronchus as a dome-like mass the lipiodol will delineate this convexity but the sign is not diagnostic as a malignant tumour projecting into a bronchus may provide identical appearances, nor is it by any means present in most bronchial adenomata

Treatment In view of the good prognosis to life as far as the purely neoplastic nature of the tumour is considered, efforts should be made to employ conservative but effective



(a)



(b)

Fig. 12.27

(a) Woman of 23 Collapse of right lower lobe Emphysema of right upper lobe
Bronchoscopic biopsy "adenoma"

(b) Radiograph of same patient four years after bronchoscopic removal and radon therapy
The lower lobe is completely re-aerated. (Dr A. Brian Taylor's patient.)



(a)



(b)

Fig. 12.28

(a) Photograph of adenoma of left main bronchus
Symptoms of haemoptysis in a woman of 40 with normal radiograph of the chest; bronchoscopy revealed adenoma of left main bronchus. This was treated by resection of the bronchus and end-to-end anastomosis. (d'Abreu and MacHale Brit. J. Surg.)

(b) Radiograph of the chest two years after resection of the left main bronchus for tumour shown in Fig. 12.28 (a) Patient alive and well six years after operation

easures Because the tumour will produce severe lung damage such as bronchiectasis chronic lung abscess, in the great proportion of patients it should be removed Before uctural damage has developed beyond the tumour there is an increasing tendency to sect it by strictly local excision such as bronchotomy or bronchial wall excision (Crafoord, 49, Price Thomas, d'Abreu and MacHale) If the occlusion of the lobe has been followed irreversible bronchiectasis, lobectomy or pneumonectomy will be required In a study the literature it is obvious that delay in recognition and treatment has led to many more eumonectomies than is desirable, but total bronchiectasis is certainly an indication for is major resection Less radical measures such as bronchotomy, or segmental or lobar sections, are being practised as knowledge of the behaviour of this tumour becomes better own

Attempts to destroy the tumour by diathermy or radium have been abandoned because the incomplete nature of the extirpation obtained A study of lobectomy specimens en shows that the large extrabronchial portion of the mass is beyond the range of broncho-opic removal, which should be reserved for palliative relief of bronchial obstruction to ow the expectoration of pent-up distal bronchial secretions in the aged or as a preparation lobectomy or pneumonectomy Any thoracic surgeon who has had experience in resecting bes or lungs, the seat of bronchiectasis after failed bronchoscopic removal or radiation erapy, is not likely to underestimate the difficulty of dissecting the hilum of the lobe or ng after this ineffective therapy which is so productive of dense peri-vascular and peri-onchial fibrosis Bronchoscopic removal, however, will always retain a small place as method of temporarily relieving bronchial occlusion and in patients who refuse more ajor surgery it may be astonishingly efficacious, as in the patient illustrated in g 12 27

This woman, aged 33, was and is under the care of Dr A Brian Taylor She was first seen another physician in 1943 at the age of 25 complaining of cough, bronchitis and slight asthma e radiograph showed a collapsed right lower lobe In 1944 Dr Taylor bronchoscoped the patient d saw a vascular tumour filling the lower part of the right main bronchus, a biopsy from which vealed the histological features of adenoma The tumour was treated by diathermy and radon eds in a Tudor Edwards container The lower lobe re-expanded but in 1945 a return of emoptysis occasioned a further bronchoscopy at which a small tumour mass was seen this s treated by further radon treatment She has remained completely well for the following five ars, is symptomless with a normal radiograph, and at full work

Bronchoscopic methods can undoubtedly relieve symptoms by checking the bleeding d by reopening a bronchus that has been occluded But criticism may be made that complete removal of a tumour that may become malignant is dangerous and may cause oncho-stenosis with resultant severe bronchiectasis accompanied by persistent haemoptysis d the expectoration of purulent sputum For these reasons resection of the tumour is eferable to bronchoscopic removal

perative procedures

I. Local resection of the involved area of the bronchial wall or trachea
II Lobectomy
III Pneumonectomy
IV Bronchoscopic treatment

The selection of the operative procedure depends on the site and size of the tumour d of the effects it has produced. Evarts Graham (1938, 1942, 1949) has adopted the view sed on pathological and clinical studies that pneumonectomy is the correct procedure

for a tumour that spreads to lung tissue and also to lymph glands most thoracic surgeons prefer a lobectomy unless the tumour involves the main stem bronchus in such a site that lobectomy would not adequately remove the tumour or remove the effects such as bronchiectasis which may have involved both lobes of the lung Resection of the bronchial wall is preferred if the tumour lies in the main bronchus and has not produced irreversible changes in the lung such as bronchiectasis or lung abscess

Rabin and Neuhof (1949) reviewed 368 cases from the world literature there were 43 lobectomies without lymph gland involvement and pneumonectomy in 60 instances 13 of which had lymph gland metastases at autopsy on 23 tumours the glands were invaded in 5 In the whole series there were 3 remote metastases but no example was seen exhibiting typical malignant extension These authors favoured local bronchoscopic removal and the account of their own 64 cases certainly produced good follow up evidence of the safety and efficiency of this treatment Nevertheless the equally good results from lobectomy incline to favour the more radical procedure which should certainly be employed if bronchiectasis has developed distal to the tumour Rabin and Neuhof themselves prefer lobectomy when the tumour is in the upper and middle lobes or in a basal bronchus because such sites place the tumour out of reach of full bronchoscopic eradication Some of the patients that reach the surgeon have irreversible bronchiectasis and lobectomy or pneumonectomy will be necessary

Resection of the tumour by bronchotomy Complete removal of the extrabronchial extension through a bronchoscope is unlikely if the tumour is diagnosed by bronchoscopy performed for haemoptysis and in the presence of a normal radiograph of the chest direct exposure of the bronchus by thoracotomy followed by excision of a portion of the bronchial wall may be justifiable and has been performed by Price Thomas and others with good results The main stem bronchus may be excised and reconstituted by end to-end anastomosis (Fig 12 28)

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PART V

THE SURGERY OF THE MEDIASTINUM

CHAPTER 13

SURGERY OF THE HEART, GREAT VESSELS AND PERICARDIUM

Introduction

However dramatic were isolated essays in cardiac surgery such as Rehn s (1897) suture of a cardiac wound and Souttar s mitral valvotomy (1925) great advances have been made since 1930 when the persistent ductus arteriosus simple or infected was first obliterated surgically (Cross and Hubbard, 1939 Tubbs 1939) Even an incomplete synopsis of the subsequent achievements must indicate a dazzling progress in excision of the coarcted segment of the aorta (Crafoord 1945) systemic artery pulmonary artery anastomosis (Blalock and Taussig 1945) the direct operative attack on valvular or infundibular obstructions of the pulmonary artery (Brock 1948) the closure of atrial and ventricular septal defects first attempted by Murray (1948) and now much advanced by the work of others such as Bailey Swan Gross Lillehei Kirklin and Sellors—these successes have been accompanied by large series of operations on the mitral valve which have restored many cardiac cripples to near normal life Aortic valve stenosis has challenged surgeons and although aortic valvotomy has limitations it is being employed increasingly The relief of tricuspid stenosis and attempts to relieve mitral regurgitation are part of a story which shows that disorders of all four cardiac valves are amenable to surgical treatment

Thoracic aneurysms have been tackled successfully by excision and replacement by aortic or plastic grafts (Bahnson Gross Brock, de Bakey)

RECENT ADVANCES IN THE SURGERY OF THE OPEN HEART

Much of the future of cardiac surgery lies in deliberate surgery performed on the open heart Brilliant work coming from several centres such as Minneapolis and the Mayo Clinic has shown that the determined efforts of Gibbon of Philadelphia who has persisted in his efforts to produce an effective method of providing an extra-corporeal circulation are now bearing fruit In Great Britain Melrose in addition to developing a heart lung machine has made a fundamental contribution by showing that cardiac asystole produced by the intra aortic injection of potassium citrate can provide a still heart for periods up to half an hour followed by rapid recovery after the potassium solution has been washed out of the coronary vessels The use of this in many patients by Kirklin at the Mayo Clinic has been a pioneering measure of incalculable benefit

The increasing use of open deliberate cardiac surgery has come rapidly and the work of Lillehei Kirklin and others has been acknowledged and seen by many surgeons working in cardiac surgery throughout the world. The reader interested in this field will have seen that progress came first through the use of hypothermia which allows the heart to be isolated from the general circulation for periods up to ten minutes at temperatures of about 29–30° C At this temperature oxygen utilization by the brain and other viscera is so reduced that closure of simple atrial defects or the deliberate incision of stenosed pulmonary valves can be safely achieved From this point the next advance was more deliberate surgery on

complex defects such as the tetralogy of Fallot with the heart totally by-passed either by the method of pumps attached to bubble oxygenators or by the type of Gibbon-Mayo apparatus

Extra-corporeal circulation

The aim of this is to protect the vital areas of the body while the heart is excluded temporarily from the circulation Hypothermia can reduce the needs of such areas for oxygen but machines can provide them with a constant supply of oxygenated blood and permit more deliberate surgery

The lung and heart circulation may both be maintained artificially, so that a pump for the heart's action and a machine capable of oxygenating blood are required The

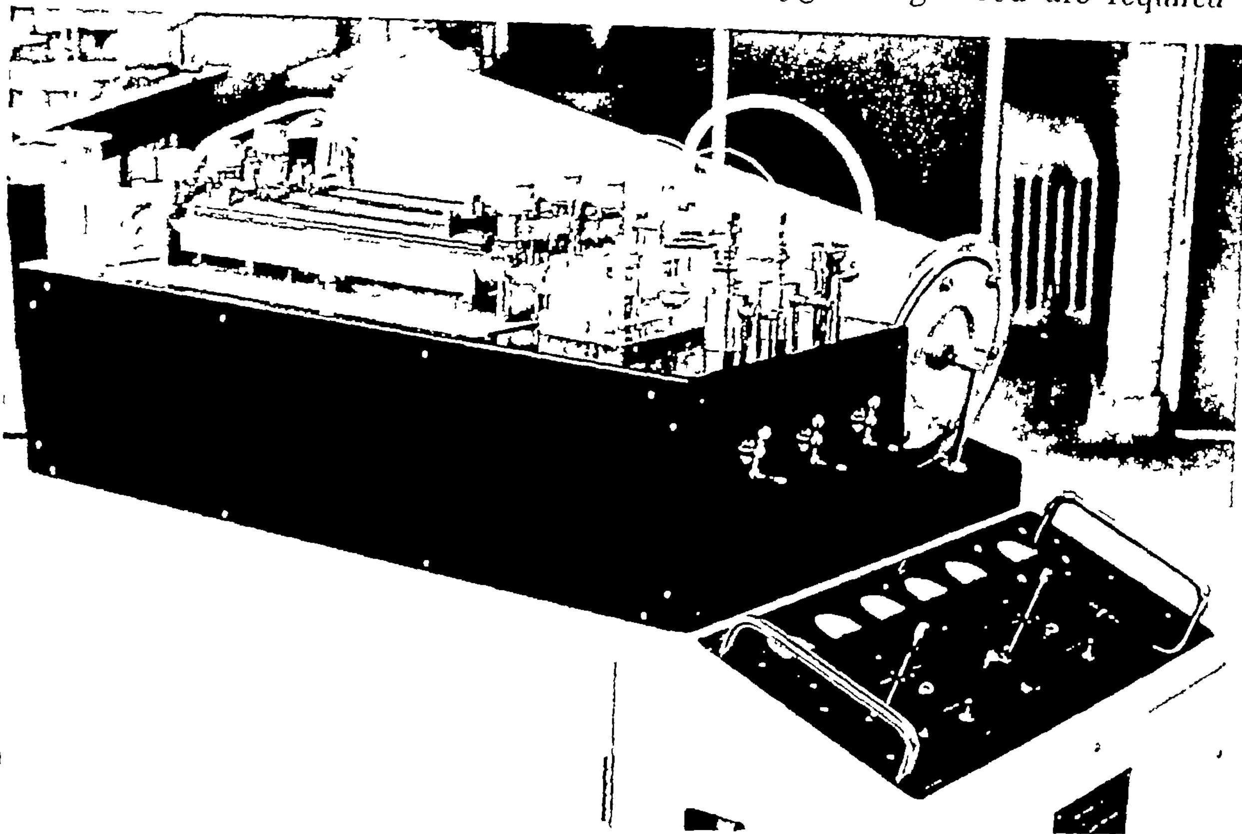


Fig 13 1 —The Melrose heart-lung machine
(New Electronic Products, London)

original difficulties of this method were that the circulation of blood through the mechanical lung damaged the cellular contents of the blood, leading to haemolysis and by its defibrinating action caused great delay in clotting of the blood that is returned to the patient The defibrination process is controlled by using heparin and better pumps and oxygenators have reduced haemolysis to a minimum By other methods, only an artificial heart pump has been tried, homologous lungs (Mustard, 1954) or the human donor lung (Lillehei and colleagues) being used for respiratory function

To produce a dry heart, both venae cavae, the aorta and the pulmonary artery require temporary occlusion inflow from the lung circulation can be stopped by tape tourniquet of the lung roots

Methods for providing both an artificial "heart" pump and an oxygenator have been described (Gibbon and others, 1937, 1954, Melrose, 1953, 1955 Jonbloed, 1949, 1950, Bjork, 1948) In Britain the Melrose machine has been developed and the method has considerable possibilities (Fig 13 1)

Undoubtedly the work at Minneapolis and the Mayo Clinic has provided the safest and most efficient methods Lillehei and his colleagues have overcome the problem of artificially oxygenating the blood by using their bubble oxygenator which does little to damage the constituents of the blood It is undoubtedly an admirable system in use It followed the use of direct human cross-circulation which always carried the fear of injury to the donor the work done by cross-circulation however permitted such deliberate surgery to be carried out that the lessons learnt from it provide a milestone in cardiac surgery At the Mayo Clinic a most efficient machine based on Gibbons work is in daily use It is expensive and requires skilled personnel for its maintenance and for its employment Its skilful use by Kirklin is acknowledged throughout the world

Principles underlying the apparatus used in extra-corporeal circulation

It is impossible to give details of the several types of apparatus in use In any system certain principles are basic blood from the right atrium is removed by two catheters made of plastic material through the agency of the venous pump which passes on the desaturated blood to the system employed for the oxygenation of the blood the essential differences in the Lillehei and Gibbon type of extra-corporeal circulation lie in the different type of oxygenator used After the blood has been oxygenated the arterial pump delivers the blood to a systemic artery usually the left subclavian or a femoral artery * The greatest care will be exercised to prevent any air embolism into the left side

Once the extra-corporeal circulation has been established by occluding both superior and inferior venae cavae around the in-dwelling catheters and the blood having passed through the oxygenator has been pumped into the systemic artery an adequate circulation of blood to the brain and other vital structures is maintained.

The cardiotomy is carried out with the heart arrested the aorta is clamped off and potassium citrate is rapidly injected into it below the clamp within a few seconds the heart s action is arrested The clamp is left in place until the end of the open cardiac surgery When the cardiotomy incision has been almost completely closed by interrupted sutures the aortic clamp is removed and blood flowing into the coronary artery rapidly washes out the potassium citrate solution and the heart s action is returned usually after a period in which there is disassociation between the atrial and ventricular contractions The incision in the heart is left partially opened to allow of the escape of blood so that excessive distension of an inactive chamber will be avoided Should arrest or ventricular fibrillation develop the measures indicated on page 71 are employed

During the cardiotomy a good deal of blood will flow from the coronary sinus this blood is kept away from the operative field by a separate cardiotomy sucker which delivers the blood back into the extra-corporeal apparatus In the open correction of the tetralogy of Fallot this coronary blood flow is extreme reaching the left atrium through the grossly hypertrophied bronchial vascular system

The two systems most commonly in use (and modifications are proceeding all the time) are those that depend on the Gibbon and Lillehei methods

The Gibbon-Mayo type of apparatus

The machine uses de Bakey roller pumps for the venous arterial and cardiotomy suction flows In brief venous blood is withdrawn from the patient to a reservoir whence it is pumped to an oxygenator This consists of a series of stainless steel mesh screens over which blood flows Oxygen is blown across the screens which are housed in a plastic case

* We find in practice that the femoral artery is satisfactory

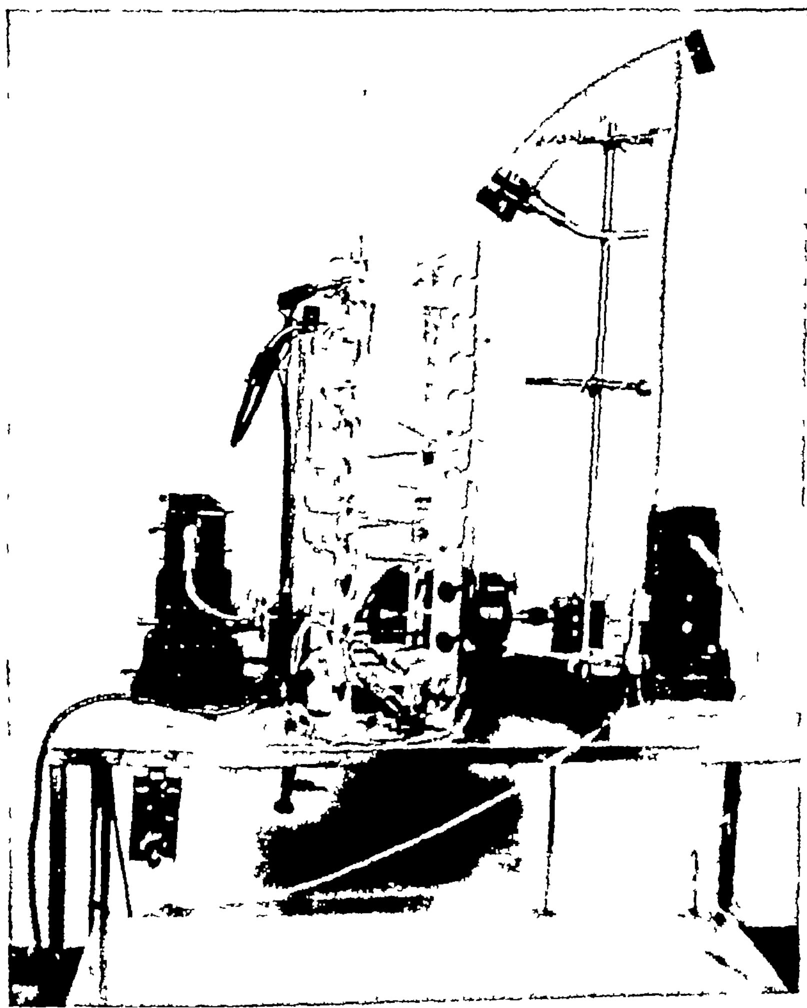
The oxygenated blood is then returned to the arterial side of the patient via the appropriate circuit The rate of circulation is automatically controlled by level sensing devices in the venous and oxygenator reservoirs Provision is also made for re-circulation of the blood within the closed system formed by the apparatus itself

Provision is made for the following variables to be continuously monitored and recorded during the surgical operation

(*A*) From the patient blood pressure in the systemic arterial and venous systems, respiration, electrocardiographic data, rectal temperature, electro-encephalographic recording

(*B*) From the machine venous and arterial saturation, pressure in the arterial outflow line artery pump output, *p*H of blood leaving the oxygenator, the vacuum in the venous reservoir

This is a precision appliance, giving a carefully controlled and well-monitored method of externally oxygenating blood It has a wide range of flows from approximately one litre to eight litres of blood per minute It is the practice at the Mayo Clinic (Kirklin, 1957) to perfuse patients at flow rates of 2 2 to 2 5 litres per minute per square metre of body surface At these high flow rates large venous cannulae, so placed in the caval vessels that they abstract fully the venous return, are essential to prevent the development of abnormally high venous pressures Throughout the perfusion the blood volume of the perfused patient should be left as normal as possible and the body temperature of the subject maintained at normal level by the use of appropriately placed warming devices on the operating table and in the machine



The bubble type of oxygenator

Lillehei and his colleagues were interested in the observation of Andreason (1953) that dogs survived for long periods when the venous return to the heart was completely cut off by temporary occlusion of both venae cavae provided the superior vena cava was clamped above the entrance of the azygos vein. The basis of Lillehei's work on controlled cross-circulation, on continuous arterial perfusion using arterialized venous blood (two methods now abandoned) and on the pump oxygenator apparatus using a "bubble" oxygenator were based on this observation that life could be maintained on this low azygos flow. Lillehei using a relatively low flow had already (1956) operated on 317 patients. Oxygen consumption rises as the flow rate is increased and the optimum rate appears to be 50–55 ml. per Kg. per minute in patients aged 2–15 years. These values are reduced by 20 per cent in adults and increased by 20 per cent in cyanotic disease.

The pump consists of a single electric motor which drives two pump heads, a venous and an arterial one, both of which had an individual speed changer. The oxygenator is made of polyvinyl plastic tubing which is discarded after each operation. Fig. 13.2 shows from right to left the vertical mixing tube into which blood is pumped by the venous pump.* oxygen is bubbled into this tube and saturates the venous blood which then proceeds to the transverse debubbling chamber and to the helix reservoir. From the bottom of the helix the oxygenated blood, now bubble free, is pumped to the patient's arterial system after passing through a filter. The helix is kept immersed in a constant temperature water bath. Larger flows than initially used are now possible.

Some details of extra-corporeal circulation operations

The operations are done through a bilateral thoracotomy incision in which the third or fourth interspace on each side is widely opened and the sternum divided transversely. The pericardium is opened widely. Polyvinyl tubes are placed in each vena cava via an incision in the right atrium; both these vessels require mobilization before they are cannulated so that tapes can be passed round them and later tightened to occlude both channels around the tubes within them. In placing the tube in the inferior vena cava the greatest of care must be taken not to pass it too far down as this would fail to drain the large amounts of blood coming from the liver. The left subclavian or a femoral artery is mobilized to be used as the channel for the entry of the oxygenated blood pumped into it from the arterial pump. This cannula is made of plastic or highly finished stainless steel.

Blood transfusion. Heparinized blood taken from donors on the day of the operation is required to prime the machine before it is connected to the patient. Extreme care is taken to see that no bubbles persist in the blood before the circuit is connected to the patient. At the close of the operation the effect of the heparin is antagonized by the administration of Protamine, the dose of which is based on clotting time estimations.

Anaesthesia. At all stages the lightest phase of anaesthesia possible is used and the amount of depressant and relaxant drugs kept to a minimum. Although the pulmonary circulation is stopped during the operation the lungs are kept moderately inflated throughout by intermittent positive pressure to prevent atelectasis developing later.

Essential monitoring. An encephalographic record is essential throughout as this is the only safe method of estimating the degree of cerebral oxygenation. This information is indeed of greater value than the electrocardiographic tracing. The arterial and venous pressures are monitored throughout by polythene tubes passed into the aorta and the inferior vena cava through a femoral artery and saphenous vein respectively. Estimation

* Gravity drainage of the blood from the caval vessels is commonly in use; we employ it in Birmingham.

The oxygenated blood is then returned to the arterial side of the patient via the appropria circuit The *rate of circulation is automatically controlled* by level sensing devices in th venous and oxygenator reservoirs Provision is also made for re-circulation of the bloc within the closed system formed by the apparatus itself

Provision is made for the following variables to be continuously monitored and recorde during the surgical operation

(*A*) From the patient blood pressure in the systemic arterial and venous systems, re piration, electrocardiographic data, rectal temperature, electro-encephalographic recordin

(*B*) From the machine venous and arterial saturation, pressure in the arteri outflow line, artery pump output, *p*H of blood leaving the oxygenator, the vacuum i the venous reservoir

This is a precision appliance, giving a carefully controlled and well-monitored metho of externally oxygenating blood It has a wide range of flows from approximately one litr to eight litres of blood per minute It is the practice at the Mayo Clinic (Kirklin, 195' to perfuse patients at flow rates of 2 2 to 2 5 litres per minute per square metre of bod surface At these high flow rates large venous cannulae, so placed in the caval vessels th they abstract fully the venous return, are essential to prevent the development of abnormall high venous pressures Throughout the perfusion the blood volume of the perfused patien should be left as normal as possible and the body temperature of the subject maintaine at normal level by the use of appropriately placed warming devices on the operating tabl and in the machine.

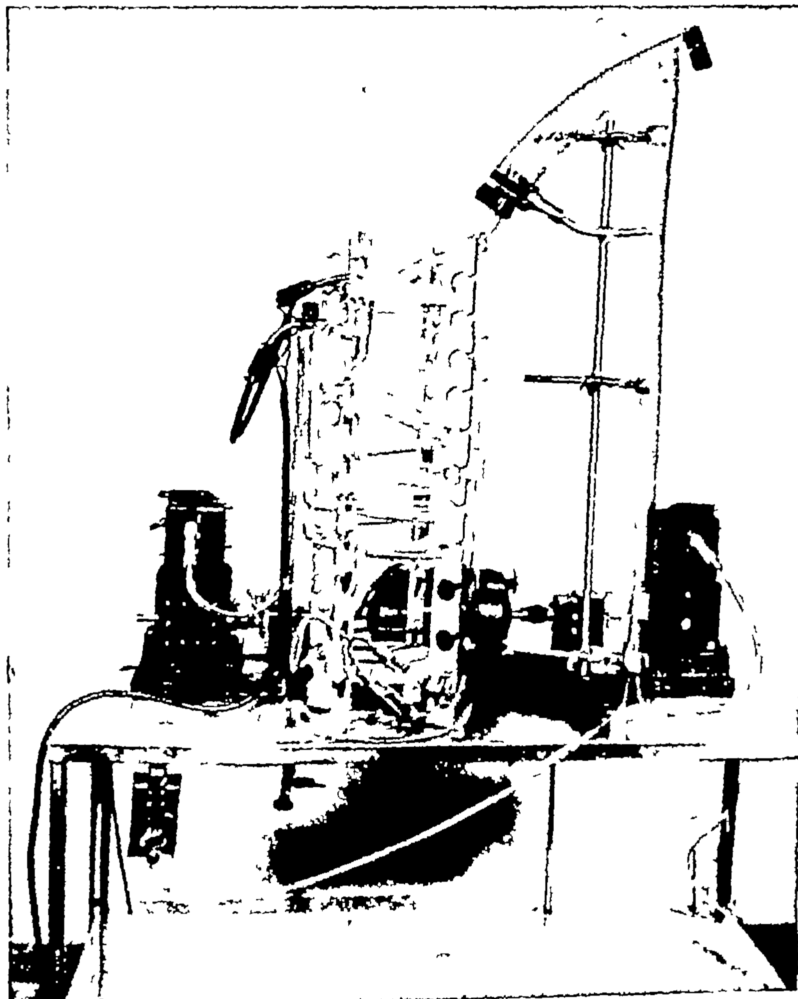


FIG 13 2 —The original Minneapolis bubble oxygenator machine

The bubble type of oxygenator

Lillehei and his colleagues were interested in the observation of Andreason (1953) that dogs survived for long periods when the venous return to the heart was completely cut off by temporary occlusion of both venae cavae provided the superior vena cava was clamped above the entrance of the azygos vein The basis of Lillehei s work on controlled cross-circulation on continuous arterial perfusion using arterialized venous blood (two methods now abandoned) and on the pump oxygenator apparatus using a bubble oxygenator were based on this observation that life could be maintained on this low azygos flow Lillehei using a relatively low flow had already (1956) operated on 317 patients Oxygen consumption rises as the flow rate is increased and the optimum rate appears to be 50–55 ml per kg per minute in patients aged 2–15 years These values are reduced by 20 per cent in adults and increased by 20 per cent in cyanotic disease

The pump consists of a single electric motor which drives two pump heads a venous and an arterial one both of which had an individual speed changer The oxygenator is made of polyvinyl plastic tubing which is discarded after each operation Fig 13 2 shows from right to left the vertical mixing tube into which blood is pumped by the venous pump * oxygen is bubbled into this tube and saturates the venous blood which then proceeds to the transverse debubbling chamber and to the helix reservoir From the bottom of the helix the oxygenated blood now bubble-free is pumped to the patient s arterial system after passing through a filter The helix is kept immersed in a constant temperature water bath Larger flows than initially used are now possible

Some details of extra-corporeal circulation operations

The operations are done through a bilateral thoracotomy incision in which the third or fourth interspace on each side is widely opened and the sternum divided transversely The pericardium is opened widely Polyvinyl tubes are placed in each vena cava via an incision in the right atrium both these vessels require mobilization before they are cannulated so that tapes can be passed round them and later tightened to occlude both channels around the tubes within them In placing the tube in the inferior vena cava the *greatest* of care must be taken not to pass it too far down as this would fail to drain the large amounts of blood coming from the liver The left subclavian or a femoral artery is mobilized to be used as the channel for the entry of the oxygenated blood pumped into it from the arterial pump This cannula is made of plastic or highly finished stainless steel

Blood transfusion Heparinized blood taken from donors on the day of the operation is required to prime the machine before it is connected to the patient Extreme care is taken to see that no bubbles persist in the blood before the circuit is connected to the patient At the close of the operation the effect of the heparin is antagonized by the administration of Protamine the dose of which is based on clotting time estimations

Anaesthesia At all stages the lightest phase of anaesthesia possible is used and the amount of depressant and relaxant drugs kept to a minimum Although the pulmonary circulation is stopped during the operation the lungs are kept moderately inflated throughout by intermittent positive pressure to prevent atelectasis developing later

Essential monitoring An encephalographic record is essential throughout as this is the only safe method of estimating the degree of cerebral oxygenation This information is indeed of greater value than the electrocardiographic tracing The arterial and venous pressures are monitored throughout by polythene tubes passed into the aorta and the inferior vena cava through a femoral artery and saphenous vein respectively Estimat'

* Gravity drainage of the blood from the caval vessels is commonly in use we employ it in Birmingha

of the pH of the blood is not necessary. If the oxygen tension in the tissues is correct there is little danger of acidosis developing. Satisfactory conditions will exist if the oxy-

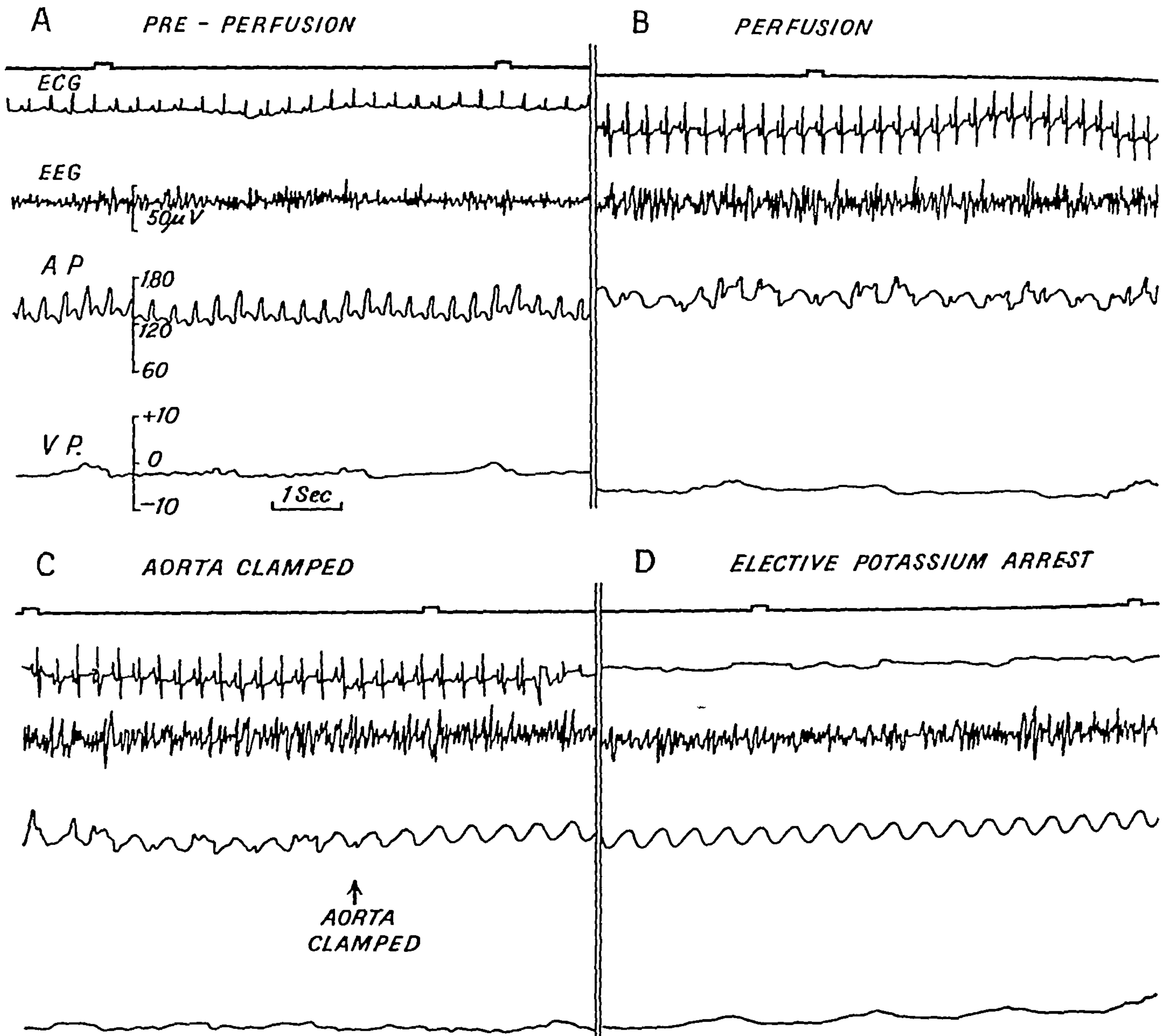


Fig 13 3

(A) A typical pre-perfusion record. The upper tracing is the electrocardiogram (Standard Lead I). The second tracing is the electro encephalogram. The two lower tracings are respectively the abdominal aortic and the inferior vena caval pressures in mm Hg. The variation in these pressures with manual ventilation is demonstrated.

(B) A perfusion record. Note the change in electrical axis of the heart due to cannulation. The slower frequency large amplitude electro encephalogram denotes a slight deterioration in cortical activity. The aortic tracing shows a combined pressure wave which is the algebraic sum of the asynchronous pulses due to the pump and left ventricular ejection. The venous pressure is negative due to gravity drainage.

(C) shows the abolition of the left ventricular component of the aortic pressure wave when the aorta is clamped prior to elective cardiac arrest, leaving the pure sine wave of the pump.

(D) shows ablation of the E C G due to potassium arrest.

(Dr W A Hudson, Surgical Research Laboratory, University of Birmingham.)

genator used adds 110 to 120 ml. of oxygen per minute per square metre of body service at a given venous oxygen saturation and at a given flow rate (Kirklin, 1957).

In the post-operative period the greatest anxieties may be caused by the development of lung oedema and the most careful estimations must be made to prevent over-hydration of the patient and the usual studies of fluid and electrolytes in the circulation are vital.

In addition to exact estimates of blood loss being made throughout the operation the patient is weighed before and after the procedure Clearly the fullest degree of oxygenation is necessary as anoxia is an important factor in producing lung oedema tracheotomy is often necessary in children

The accuracy with which the protamine dosage can be assessed has obviated the dangers of post-operative bleeding the most exact measurement of blood loss throughout the operation is essential.

Hypothermia in cardiac surgery

Short operations on the open heart can be carried out at temperatures between 29 and 30 C At lower levels the risk of ventricular fibrillation rises The reduced metabolic rates and oxygen needs that accompany hibernation or artificially induced hypothermia enable neural and cardiac tissue to survive after limited periods of oxygen lack (6–10 minutes) A total obstruction of the inflow and outflow tracks of the heart for periods of six to ten minutes to enable direct opening of the heart chamber and the direct closure for example

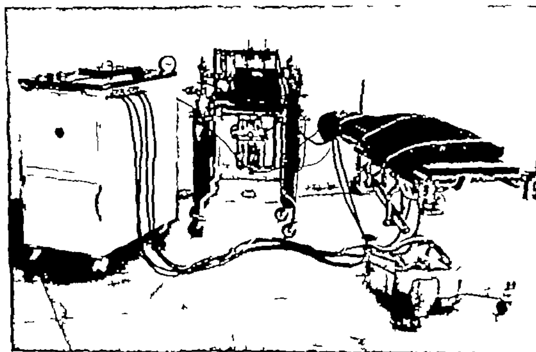


Fig 13·4 —Cooling by surface blanket.
Photograph of apparatus for cooling. (Birmingham pattern. Prestcold, Oxford.)

of an atrial septal patency (Lewis and Taufic 1953 Swan, 1954) is possible provided special measures are adopted to prevent coronary and cerebral air embolism (see page 400) By this method short open operations for the relief of aortic or pulmonary valve stenosis are possible The method has proved its value in operations for the closure of ostium secundum defects of the atrial septum

Artificial cooling may be accelerated by the so-called hibernating drugs such as chlorpromazine used in combination with the external or internal method *External cooling* is produced by placing the patient in a cold bath or by means of a blanket through which cold water is driven (see Fig 13 4) The blanket method is especially applicable *to children* whose temperature can be brought down to 30–31° C within 1 hour adults require a longer time and immersion in a cold bath is quicker (Sellick 1957) By the *internal method*

an artery or a vein is cannulated and the blood, after passing through a cooling mechanism, is returned to the body by another vein * This method is naturally more complicated than the blanket method of external cooling but has a good application in adult patients. During the cooling process, anaesthesia and relaxant drugs are required to prevent shivering, which makes high metabolic demands at temperatures below 35° C very little anaesthetic agent is required The chief danger of the method is that ventricular fibrillation is possible at temperatures below 28° C and a ventricular defibrillator must always be available. Although cooling delays clotting, the bleeding problem in practice is not a real one

At the moment of writing, hypothermia is being used mainly for open cardiac surgery for the closure of atrial septal defects and the open division of the stenosed pulmonary or aortic valves

SURGERY IN ACQUIRED DISEASES OF THE HEART AND GREAT VESSELS

Diseases of the pericardium

Rheumatic inflammation provides the commonest disease of the pericardium Its exudative reactions resolve in recovering patients with the production of minor or gross pericardial thickenings which partially or wholly obliterate the pericardial sac Such adhesion formation does not produce true constrictive pericarditis and operation experience in rheumatic heart disease shows that most extensive pericardial changes fail to limit cardiac dilatation Cardiac embarrassment caused by overlying effusions or by the strangling effect of contracting fibrous tissue due to various conditions requires mechanical relief

Effusions

Surgical relief of acute cardiac embarrassment due to fluid pressure may be required in (1) rheumatic pericardial effusions, (2) tuberculous pericarditis, (3) pyogenic pericarditis, (4) cardiac tamponade due to trauma

Whether the heart be compressed by fluid, pus or blood, with or without associated air, the clinical features are the same Beck's triad provides the best clinical evidence Beck (1937) indicated that acute cardiac compression provides some features quite distinguishable from chronic constriction The "acute" triad consists of a rising venous pressure, a falling arterial pressure and a small quiet heart

As compression is sudden the veins have not had time to stretch in spite of the rise of venous pressure caused by the compression of the heart and the venae cavae the fall in venous return will, of course, lead to a decrease in cardiac output providing signs of arterial failure with the clinical features associated with anoxaemia—skin pallor, feeble pulse (which may show pulsus paradoxus), an anxious expression and attacks of fainting The precordial pulsation, previously tumultuous in patients with rheumatic carditis, becomes less and the heart sounds faint Radiologically the size of the cardio-pericardial outline differs greatly, depending upon the distensibility of the sac which varies in different individuals Severe compression may accompany a not very large shadow and the clinical features are more important than the radiological ones Large effusions by compressing the left lower lobe bronchus may produce atelectasis

The diagnosis of rheumatic pericardial effusions from other causes depends on the history and the previous presentation of typical rheumatic conditions, signs and symptoms and a pericardial friction rub which usually precedes the effusion With absolute rest and administration of salicylates the condition often subsides without the full development of

* Brock's and Ross's method of producing this type of hypothermia is described on page 104

Beck s triad of acute compression but if this is present and the circulation is embarrassed aspiration of the compressing fluid is essential

Tuberculous effusions are more insidious in onset and a typical rheumatic story is lacking an associated or preceding pulmonary tuberculosis may have been diagnosed and when signs of cardiac compression develop in a patient undergoing sanatorium treatment the diagnosis is readily suspected More commonly the condition develops slowly with malaise listlessness dyspnoea and cyanosis following what may have been considered influenza or pneumonia The tuberculous effusions because of their slower development distend the sac more and the radiological outline of the heart may be very large An absolute diagnosis will be made by finding the tubercle bacillus in the aspirated fluid

Treatment of tuberculous effusions Whether there is associated lung tuberculosis or not the patient must be at complete bed rest The indications for pericardial paracentesis are as in rheumatic effusion If aspiration is employed streptomycin (1 gramme) should be left in the sac at the close A full course of antibiotic and chemotherapeutic treatment is essential streptomycin with P A S and isonicotinic acid should be given for six months or longer if the condition responds to a conservative regime

Perhaps the most important thing in the management of the tuberculous pericardial effusion is the need for watchfulness for early signs of the development of cardiac com pression and pericardial constriction If the radiograph shows a great increase in the size of the cardiac outline it may be assumed quite wrongly that the condition is one of effusion only even though the veins in the neck are becoming more obvious and ascites and hepatic enlargement is developing If clinical evidence of true constriction of the heart develops there should be little anxiety about operating in a subacute phase because true contraction of the visceral pericardium will not commence until healing has partly started Strepto-mycin seems to be most efficient in preventing any spread of the tuberculous process else where in the body if operation has been carried out Radiological appearances may deceive by providing a large cardiac silhouette in spite of such a shadow a considerable amount of fluid in the pericardial sac may be found at operation in a patient with the classical features of constrictive pericarditis and the heart beneath the tuberculous caseous effusion will be small and gravely strangled

Purulent effusions

Although Romero (1819) first drained a purulent pericarditis with success early in the nineteenth century the death rate from the condition is still about 50 per cent and surgical drainage is apparently only rarely performed Truesdale (1933) could collect only 152 examples of this operation in the literature and this survey revealed a death rate of 42 per cent it may be presumed that many unavailing operations have never been reported In generalized septicaemia patients may die with this condition as a preterminal com plication the autopsy findings revealing a fibrinous or sero-fibrinous pericarditis without cardiac compressions An important group of patients however develop a purulent effusion as a complication of pneumonia or empyema Donaldson (1943) believes that only half the patients with purulent pericarditis are diagnosed in life

Diagnosis It is unwise to expect that all the physical signs classically associated with the disease will be present Pyrexia tachycardia and cyanosis are usually associated with dyspnoea the neck veins may be engorged enlargement of the cardiac outline may not necessarily be associated with distant cardiac sounds as the fluid may be located chiefly in the posterior pericardial compartment with the apex beat displaced forwards but radiology

will be of great assistance in demonstrating the feebleness of the cardiac movements Pulsus paradoxus may be present

A high pyrexia, often due to the causative septicaemia, is important in association with signs of acute cardiac compression When the disease develops in the course of a septicaemia or pyaemia, or following a major thoracic operation such as pneumonectomy, it may be overlooked, as the toxaemia, feeble pulse, cyanosis and other features may be ascribed to pleural or pulmonary complications

Treatment. Immediate surgical drainage is required as soon as a pericardial paracentesis has produced evidence of pyogenic infection Urgent relief by surgical evacuation is essential to relieve the burden of a compressed heart in a highly toxic patient and to prevent the danger of loculation taking place such loculation will be favoured by attempting cure by aspiration and the instillation of antibiotic or chemotherapeutic agents.

Haemo-pericardium Apart from rare causes such as rupture of an aneurysm, scurvy or malignant tumours, gun-shot wounds and stab wounds are the exciting agents In warfare the site of entry may be near or in distant areas cardiac tamponade may not necessarily develop rapidly, but whether fast or slow, continuing bleeding will produce the classical Beck triad and urgent surgical exploration will be needed * Foreign bodies impacted in the parietal pericardium or the myocardium may cause a blood-stained effusion, tense enough to compress the heart

The technique of pericardial paracentesis This is performed under local anaesthesia with suitable premedication A wide-bore needle is no more dangerous than a narrow one and should be used it should be at least 2 mm in diameter smaller needles become blocked by fibrinous exudate and their use is not uncommonly the cause of error in diagnosis as failure to produce fluid may be taken as an indication that none is in fact present Of the several possible sites such as the fourth left interspace 1 5 cm from the sternal edge, the fifth space just outside the assessed site of the apex beat (often difficult to determine), posteriorly in the scapular line in the seventh space or to the side of the ensiform cartilage, the last mentioned is the most safe and efficient

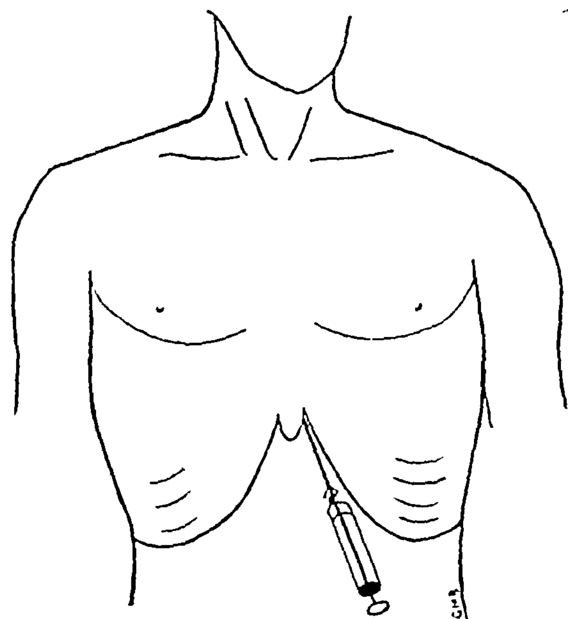


Fig. 13 5 —Aspiration of pericardial effusion at the side of the ensiform cartilage

The needle is directed upwards, backwards, and inwards and the depth of penetration is deeper than in the anterior approach through the left fourth or fifth space, but it strikes the area where fluid most readily gravitates, where the potential size of the pericardial sac is the greatest and where there is least danger of injuring a coronary vessel should the heart be inadvertently pierced The needle is inserted as close as possible to the apex of the angle formed by the ensiform cartilage and the cartilaginous costal margin Aspiration alone is indicated in the rheumatic effusions causing compression but in tuberculous pericarditis 1 gramme of streptomycin should be left in the sac after each withdrawal of fluid If pyogenic pus is withdrawn the indication for

* Paracentesis alone can relieve tamponade due to haemo-pericardium, aspiration should always be practised and if improvement is maintained it will suffice deterioration is an indication for surgical exploration (see page 325) which has been used in 25 per cent of the cases reported by De Bakey

surgical drainage exists but penicillin should be installed as the withdrawn sample will have to be examined bacteriologically before surgical intervention is finally invoked

Drainage of purulent pericardial effusions The variety of approaches that have been used indicate that the problem is not simple but the principle of establishing drainage at the most dependent point (first suggested by Allingham in 1904) appears each year to become more firmly established. Donaldson's approach (1943) has the attractiveness of simplicity and directness this approach to the pericardium is through the perichondrium of the seventh left costal cartilage which is resected for two inches immediately adjacent to its junction with the sternum The approach is technically a more simple one than that made in the angle formed by the ziphisternum and the costal margin and there is no danger of opening the peritoneal cavity

The other operations of access through resection of the fifth or sixth left costal margin are too high to allow drainage of the lowest recess of the sac and their use may endanger the pleural cavity This latter risk is even more formidable in a posterior approach in which the pericardium is approached extrapleurally after resection of the posterior ends of one or more ribs

When the pericardial sac has been opened and most of the pus has drained out the pericardial sac should be gently irrigated with normal saline and the finger used to explore its posterior recesses to ensure against loculation The maintenance of the drainage opening is not easy large tubes left in the pericardial sac have the obvious potential risk of damaging the heart wall A large flanged catheter should be left with its flange just within the sac and when this site has been judged it should be sutured to the skin the skin and soft tissue should be left widely open and the patient's position changed regularly to a semi prone or prone one at different intervals throughout the day to encourage drainage Daily saline irrigation is followed by penicillin instillation or other antibiotics appropriate to the organism detected The major post-operative difficulty is to maintain an adequate drainage opening for a sufficient length of time

Constrictive pericarditis (concretio cordis)

The surgical relief of the crippling effect upon cardiac output produced by the deposition and contraction of fibrous tissue on the visceral and parietal pericardium will be disappointing if employed too late Delayed excision of the strangling fibrous tissue does not allow the atrophied muscle fibres of the myocardium to recover rapidly nor permit the dynamics of the circulation to be restored adequately Moreover in late cases of constrictive pericarditis associated with polyserositis the liver may become permanently damaged and the relief of ascites may be disappointing

Pathology Healing tuberculous tissue has the greatest power of contraction here as in pulmonary disease and although other etiological processes may produce a constrictive pericarditis tuberculous disease is the basis of the typical picture Rheumatic disease frequently productive of intrapericardial adhesions does not cause true heart constriction for vascular rheumatic adhesions do not contract to any great extent nor do they prevent the enlargement of the chronic rheumatic heart associated with involvement of the pericardium Paul White (1935) thought that if rheumatism could cause Pick's disease it did so in only the rarest cases Quite exceptionally a persistent contracting fibrosis follows a suppurative pericarditis or haemo pericardium Blalock and Burwell (1941) reported pericardiectomy in 20 patients in 13 the etiology was tuberculous in 3 it followed a previous staphylococcal infection and in 4 the exact cause was not determined

The evidence for a tuberculous etiology depends on clinical observations the histological

appearance of the excised pericardium and the discovery of tubercle bacilli An increasing number of patients are seen in whom the progress from tuberculous pericardial effusion (tubercle bacilli being recovered from samples obtained at paracentesis) to constrictive pericarditis can be observed during their sanatoria regime (Fig 13 6) The risk of producing dissemination of the disease by operating in a subacute phase is decreased by using streptomycin and pericardiectomy is sometimes performed when the disease is still proliferative The tissue excised at such operations shows a more characteristic construction than in



(a) (b)

Fig 13 6

(a) Radiograph of chest showing bilateral pulmonary tuberculosis and a small heart shadow
The patient had ascites and advanced signs and symptoms of constrictive pericarditis

(b) The post-mortem appearances
A small heart with considerable thickening of the visceral and parietal pericardium The pericardial sac in parts of its diaphragmatic aspect is not completely obliterated

specimens removed after the tuberculous activity has died down to be succeeded by a dense fibrosis, sufficiently intense to have destroyed the evidence of characteristic tubercles The high incidence of calcification supports a tuberculous etiology

A tuberculous serous pericarditis, like a pleural effusion, may absorb completely, with or without aspiration but as in the pleura an increase in cellular and protein content of the fluid is followed by a deposit of fibrin and collagen on both pericardial layers, which become organized into hyaline fibrous tissue with all its potentiality for extreme contraction It is the strangling effect of the fibrosis on the visceral pericardium that produces the characteristic pathological and clinical effects the heart muscle, apart from invasion by septa of fibrous tissue remains essentially normal, but the constricting process interferes especially with the diastole of the ventricles The deposition of fibrous and calcified tissue does not follow any set formula and in some patients the constriction of the heart is most obvious over the left atrium and left ventricle

Calcification is seen in advanced disease along the borders of the heart frequently forming rings around the entrances of the great caval openings fibrous and calcified plaques may interfere with the cardiac conducting tissue and this no doubt is the cause of such irregularities as atrial fibrillation

The small indistensible heart receives a diminished supply of blood with a consequent reduction in cardiac output there is a steady rise of venous pressure visible and measurable in the veins of the neck the liver enlarges and ascites follows The peritoneal fluid is a transudate unless there is tuberculous peritonitis as well as pericarditis Pleural effusions oedema of the legs and cyanosis are also present in severe degrees of constriction In long standing ascites the liver spleen and peritoneum become covered by a dense white layer of fibrous tissue (icing sugar coating)

Diagnosis Ascites raised venous pressure and a quiet heart (Beck s triad) indicate clearly the diagnosis in a patient who is also dyspnoeic on exercise who often looks ill and malnourished though some appear well while at rest In addition to the peritoneal effusion one or both pleural cavities may be the site of effusion The outstanding feature of ascites may prompt a false diagnosis of hepatic cirrhosis of doubtful etiology but in my own experience the patients most frequently misdiagnosed are those who show atrial fibrilla tion with gross peritoneal fluid. In the group with ascites and pleural effusion the chest radiograph not infrequently shows evidence of healed or active tuberculosis and the whole picture may be regarded as one of pulmonary and abdominal tuberculosis as was so in three of my pericardiectomy patients When the diagnosis has been overlooked the patients have usually been mislabelled as suffering from tuberculous peritonitis cirrhosis of the liver valvular heart disease and ascites of unknown etiology (Churchill 1935)

Blalock and Burwell (1941) though stating that the diagnosis can usually be estab lished with confidence indicate mistakes that have been made and give the following list of possible errors

Other types of pericardial disease Pericardial fluid mediastino-pericarditis and poly serositis (this last is often associated with true constrictive pericarditis)

Diseases of the heart (*a*) Tricuspid valve disease (*b*) diseases accompanied by failure of the right ventricle mitral stenosis cor pulmonale myocardial disease

Extracardiac disease (*a*) Cirrhosis of the liver (*b*) mediastinal tumours (*c*) nutritional oedema, (*d*) multiple thrombosis of veins (*e*) conditions associated with marked increase in intrathoracic pressure

Once the true nature of the condition has been suspected an accurate diagnosis is made by noting (1) the obvious rise in venous pressure, seen especially in the neck veins which show visible pulsation and confirmed by the recording of the actual pressure which may be as high as 300–400 m m of water (2) By the presence of ascites and possibly of pleural effusions (3) The clinical and radiological demonstration of a quietly beating heart The radiological shadow of the cardiac area may be larger than usual because of the mass of pericardial fibrous tissue but screening and the use of the kymograph will indicate the reduction in the heart pulsation The heart sounds are usually faint (4) Calcification of the pericardium when present is conclusive evidence but occasionally the differentiation from calcification in the heart itself (which is not usually associated with constrictive pericarditis) may be required (5) A low systolic blood pressure with a small pulse pressure accompanies a tachycardia which seems to offset the lower cardiac output Pulsus para doxus is usually but not always detectable and in 20 per cent of the patients auricular fibrillation is present (6) Characteristically the electrocardiograph shows a low voltage and the T waves may be inverted (7) Reduced cardiac output and usually a rise in the

pulmonary artery pressures (8) Cardiac catheterization reveals diastolic hypertension affecting both sides of the heart equally.

The aims of surgical treatment. The release of the heart from its constricting envelope can only be achieved by pericardiectomy which must expose and free enough of the cardiac muscle to allow satisfactory diastolic filling. Unsatisfactory results are largely due to inadequate excision of the fibrous or calcified envelope but a complete excision, though theoretically indicated, adds to the operative risk of opening the heart chambers, especially the thin-walled atria. Opinion is divided as to the need for complete freeing of the areas of entrance of the inferior and superior venae cavae. When these are encircled by calcified tissue their surgical liberation is dangerous and most surgeons believe that a wide freeing of the borders of the heart is sufficient: this entails a wide decortication of the right and left ventricles and the complete freeing of the inferior border of the heart from the diaphragm. The fixation of this area of the heart to the diaphragm leads to limitation of its filling and contraction during inspiration and produces the phenomenon of pulsus paradoxus (Holman, 1949).

Holman (1949) favours extensive removal and because of this advocates a wide sternum splitting approach in preference to a left extrapleural or transpleural exposure. Churchill (1949) believes that the chief interference with cardiac function is on the left side and proposes a wide decortication of the left ventricle and the entrance of the pulmonary vein into the left atrium and points out that constriction at this area may simulate advanced mitral stenosis. The necessity for a freeing of the left side of the heart is becoming more and more generally accepted. In spite of the radiological absence of pulmonary plethora on the radiograph, cardiac catheter studies invariably disclose pulmonary hypertension.

To provide a full exposure of the pericardium a trans-sternal approach with a bilateral thoracotomy through the fourth space on each side is excellent and I believe will be used more frequently. Its advantages have been well described by Bigelow (1957).

An experience, common enough to most surgeons, that a second operation is not infrequently required for the purpose of further removal of the constricting membrane points to the need for thorough freeing, but all operations must be executed as safely as possible and a too ambitious dissection over the thin-walled atria may be unjustifiably dangerous. It is most unwise to attempt decortication in areas where the operative field is not in good view: the temptation to free the right ventricle widely through a left-sided approach once led me into the grave difficulty of having to deal with a tear into the chamber of that ventricle after a badly judged attempt to free an area without a good enough exposure. The necessity to improve diastole of the right as well as the left ventricle is not entirely met by the usual left parasternal or transpleural approach, and in the future the extensive median sternotomy approach advocated by Holman may find more supporters. Sweet of Boston has increased the exposure by splitting the whole length of the sternum. The exposure it gives enables a safer stripping of the thinner right ventricle to be done: in the left-sided approach it is easier to free the left ventricle more widely as this area of the heart is thicker in muscle, usually less firmly bound down by fibrous tissue and easier to see.

Having employed the sternum splitting approach for a time, I have returned to the left-sided approach as the necessity for clearing the back of the left ventricle has appeared to be more and more advisable.

The timing of surgical intervention. The difficulties of this problem include attention to two main factors: the inadvisability of operating too early on a febrile, ill patient with active tuberculous disease of the pericardium and delaying too long a surgical

correction of a severe mechanical embarrassment that may progress steadily not only with further deterioration in the patient but with the great risk of increasing the surgical difficulties because of the increasing denseness and calcifying nature of the fibrosing process If the patient is seen in the early stage of tuberculous serous pericarditis with commencing signs of cardiac compression treatment will consist of rigid bed rest, general constitutional management and aspiration of the fluid Streptomycin should be given parenterally combined with para aminosalicylic acid to decrease the chance of providing a resistant strain Such a patient need not necessarily proceed to constrictive pericarditis and throughout this period the elimination of tissue fluid is encouraged by the use of diuretics such as Mersalyl and by a low sodium diet If the true picture of constriction develops the choice of time for operation will depend on reduction in any existent pyrexia and a drop in the sedimentation rate ascites and pleural effusion being dealt with by aspiration If the mechanical effects of the constriction steadily increase the operation should not be delayed and the risks of tuberculous infection can be combated by streptomycin therapy many patients with living tubercle bacilli present are safely piloted through operation

Pre-operative treatment A period of bed rest in hospital is required. Every effort is made to decrease excess tissue fluid by restricting fluid intake and placing the patient on a salt-free diet and by the exhibition of mercurial diuretics fluid in the pleural and peritoneal cavities is thoroughly aspirated Digitalis, which decreases cardiac output, is not prescribed unless the constrictive process is complicated by atrial fibrillation with tachycardia or by myocardial insufficiency (Burwell 1940) Many of the patients with polyserositis have low protein plasma levels and a high protein diet is indicated especially if liver function tests indicate a change in the globulin albumin ratio

The operation Because of the poor cardiac output the induction of anaesthesia causes special hazards as pentothal causes a peripheral vaso-dilatation this sudden drainage of blood may be dangerous To ensure rapid intubation of the trachea a relaxant is used with a minimal amount of pentothal the lungs are fully ventilated with a high proportion of oxygen mixed with nitrous oxide Anaesthesia is kept at a light level To decrease the venous congestion the operating table should be in a partial anti Trendelenburg position Three surgical approaches are available

(a) *The left extrapleural approach* A large musculo-cutaneous flap is turned laterally after a mid line incision has been made from the second to the sixth left costal cartilage The third, fourth and fifth cartilages are divided or resected the left pleura is displaced laterally by blunt dissection after ligation and division of the internal mammary vessels The exposure given by this operation is not very wide

(b) *A left intrapleural approach* The third left intercostal space is widely exposed and opened the third and fourth costal cartilages are divided close to the sternum and a rib spreader introduced the exposure obtained is superior to that of the para sternal approach and with good anaesthesia and sound post-operative care of any resultant pleural effusion there are no disadvantages in operating across an open pleura

(c) *By median sternotomy* This provides an excellent exposure and the divided sternum heals rapidly A mid line incision starts at the level of the second costal cartilage and reaches to the ensiform cartilage which may be resected The space behind the posterior surface of the lower end of the sternum is easily developed by pledglet and finger dissection and the sternum split by the use of Schumacher s bone cutter or Lebsch s sternum splitting knife up to the level of the second costal cartilage At this level the sternum is bisected laterally at right angles to the longitudinal lower section and a wide exposure is obtained by the use of a strong Tuffier s retractor The pleura on one or both sides may be torn

accidentally but with intratracheal anaesthesia this is of little moment and the torn area is temporarily closed by a moist saline pack until it is repaired at the close of the pericardiectomy. The closure of this wound is by two wire sutures through drill holes on each side of the line of resection and supplemented by interrupted unabsorbable sutures in the periosteum and pectoralis muscle

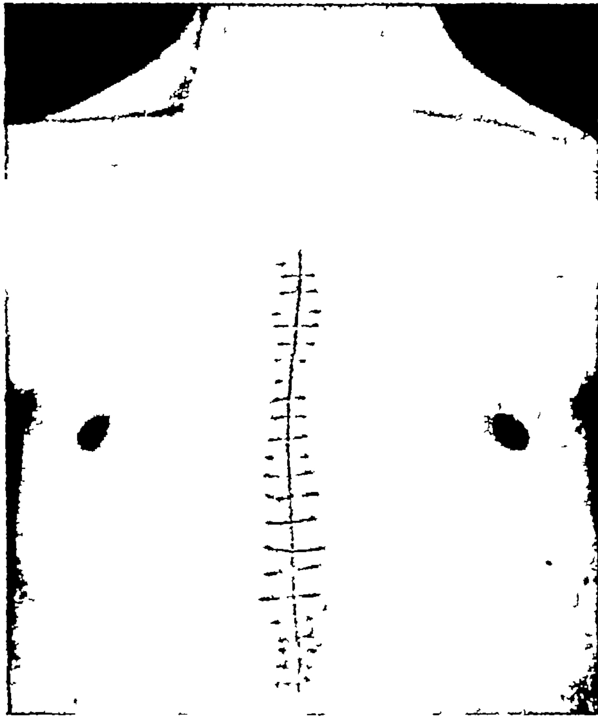


FIG 13 7 —The incision after the median trans-sternal approach For constrictive pericarditis

The exposed pericardium presents varying degrees of fixity and thickening The parietal pericardium is cautiously incised and flaps of it well raised before any attempt is made to separate it widely from the visceral or epicardial layer, the decortication of which is the important part of the pericardiectomy a plane of cleavage between the two layers of the pericardial sac is usually not difficult to develop, the area of adhesion between these being most intimate over the right ventricle The raised flaps of parietal pericardium are held upwards and laterally and segments resected sufficiently to expose the true layer of the constricting fibrous tissue, the visceral pericardium this is incised with the greatest deliberation until cardiac muscle is exposed and it is elevated by blunt and sharp dissection At as early a stage as possible the left phrenic nerve is defined and damage to it is avoided Areas of adherent pericardium over the site of the left descending coronary artery are left unresected The left ventricle is decorticated as widely as possible, well beyond the line of the phrenic nerve, before the right ventricle is uncovered to avoid the risk of over-distension of that chamber before the diastolic stretching of the left side has been allowed to deal with the increase of blood flow from the lungs Frequently the area of excision stops at the atrio-ventricular groove to avoid risk to the coronary artery branches there, and to ensure against tears in the thin atrial walls But the heart must be freed completely from its diaphragmatic area of adhesion and at any areas where pulsation is markedly limited As the decortication proceeds the heart expands visibly into the wound and bulges obviously In the hope of decreasing the frequent extrasystoles and irregularities that accompany the manipulations, applications of 5 per cent procaine have been advised This is not necessary and such solutions may have local irritating effects If the irregularities become marked and embarrassing to the circulation, periods of rest from actually operative removal of the membrane are more effective than procaine applied locally

At the conclusion of the operation the pericardium is allowed to drain into one or other pleura If a median sternotomy has been used an opening is made deliberately into the left pleural cavity any fluid that exudes can be readily dealt with by pleural aspiration

Post-operative treatment. The need to continue the pre-operative dehydration measures is obvious and for the same reason intravenous fluid should not be given and blood transfusion is contra-indicated unless there has been a serious operative loss which is unusual Oxygen is given for patients with cyanosis and digoxin again is employed only if atrial fibrillation with tachycardia is present

SURGERY OF VALVULAR STENOSIS

All four valves of the heart have now been operated upon in this section attention is devoted mainly to the surgery of the mitral valve and secondarily to the aortic one I think that every surgeon and physician who has followed up a reasonably large series of mitral valvotomies has no doubt that the operation has become fully established and that in many instances it is being withheld unfairly from many cardiac cripples who could return to a normal and happy life It is not possible yet to assess properly the role of the operations being performed for severe mitral regurgitation some progress has been made in the surgery of the stenosed aortic valve and in the relief of aortic regurgitation

MITRAL STENOSIS

Large series of operations and many articles have been published since the papers of Bailey (1950) Brock (1950) and Harken (1950) stimulated surgeons to operate on these dyspnoeic patients Raised pulmonary artery and pulmonary capillary pressures have been shown by cardiac catheter studies to have been lowered and the continued good clinical condition of most of the patients several years later has been maintained Re-stenosis undoubtedly occurs but it is rare As expected in some patients with the passage of time deterioration has set in when the myocardium was poor other valves were affected or the actual surgical treatment of the stenosed valve at the time of the operation was not satisfactory If surgery is delayed too long the pulmonary hypertension which is due to increased resistance in the arterioles and small arteries and which is reversible for long periods may become fixed as the result of permanent medial and intimal fibrous thickening and scarring

It is much easier to indicate the type of patient the surgeon likes to see than to know when to withhold operation in the bad risk group In the last five years, accuracy in diagnosis has been much improved and the indications for cardiac catheterization as an aid to the selection problem has become clearer (See Chapter 15)

The classification of the American Heart Association provides some guide as to the assessment of the severity of the symptoms and the state of the patient

Class 1 No limitation of physical activity no discomfort on ordinary physical activity
Class 2 Slight to moderate limitation of physical activity less than ordinary physical activity causes discomfort
Class 3 Moderate to great limitation of physical activity less than ordinary physical activity causes discomfort
Class 4 Unable to carry on any physical activity without discomfort

No responsible writer has advised surgery in Class 1 but patients in this group *often* pass into the next one which should provide the largest number of ideal candidates for *operation* It is in Class 2 that doubt may be expressed as to whether the symptoms are severe enough to warrant operation In such patients, cardiac catheterization *findings* are often of great value an estimate of the degree of pulmonary hypertension is possible by comparing the pressures in the pulmonary artery with those in the left *atrium* *The* accuracy of regarding the atrial pressure as being the same as the pulmonary capillary venous pressure has been verified by Allison s method of obtaining direct arterial pressures through a needle passed through a bronchoscope The role of catheterization has been considered in Chapter 15

Class 3 patients are often suitable for valvotomy; the reputation of the operation has been damaged by the acceptance of too many bad risks from Class 4 when the indications were more speculative and the technique of the operation had not been perfected. Nonetheless, patients in this group who have been operated upon have provided some outstanding successes. *A mortality rate of 10–20 per cent must be accepted in Grade 4 cases.*

Indications for valvotomy

Since so many factors may complicate the course of rheumatic heart disease the attempt to outline indications away from the bedside and the patient is a task full of pitfalls. Nevertheless, certain broad features have emerged in the last five years and decisions have become easier. All patients with mitral stenosis who have significant symptoms should be considered for surgery. Ideally, the patient should be under fifty, free from rheumatic activity, in sinus rhythm, with no evidence of cardiac failure and with a reasonable response to exercise. *Such a patient with pure stenosis should have a reasonably small heart and* electrocardiographic evidence of right ventricular preponderance. The operative mortality rate will be low (under 1 per cent) and complications such as embolism rare.

Less ideal but nonetheless acceptable, are patients under sixty who have been in cardiac failure. In this group are those who urgently need valvotomy for the relief of nocturnal and paroxysmal dyspnoea, pulmonary oedema and recurrent haemoptysis. Many have atrial fibrillation and the greatest complication of valvotomy, arterial embolism, mars the results in this group. *Nonetheless, many fibrillators have been grateful for the relief* provided by operation. The heart will be larger, with great increase especially in the size of the right ventricle, the left atrium and the pulmonary artery; such changes will be accompanied by the clinical and radiological features of pulmonary hypertension.

In the next group of patients, the results will be the poorest; those with a history of many attacks of failure, with greatly enlarged hearts, poor exercise response, atrial fibrillation, significant associated mitral regurgitation and previous arterial embolisms.

In all groups, calcification of the mitral valve, best seen by radiological screening, will diminish the chances of a good result, though this is by no means always so.

*Mitral regurgitation of a degree sufficient to produce a large left ventricle contra-*indicates valvotomy. In some patients with mitral stenosis, there is a slight degree of regurgitation; operation, by producing a competent *functioning* valve, *may* correct this regurgitation.

Pulmonary hypertension of all degrees is met with; although advanced degrees may be irreversible, hypertension is a strong indication for surgery as the lung congestion and the commencing right ventricular hypertrophy will be relieved. Many cardiac catheterization studies have now been carried out before valvotomy and six months after operation, which show that high pulmonary pressures may drop significantly. It is interesting and important to note that although the pulmonary arterial pressures may drop after satisfactory valvotomy the pressure still rises abnormally on exercise as measured by the catheter.

The influence of disease of other valves

Many patients with aortic valve lesions of slight degree have been taken through mitral valvotomy with good results and operation is not withheld if the chief cardiac dysfunction is due to the mitral stenosis. Considerable left ventricular enlargement and the other signs of aortic stenosis of severity will probably alter the surgical plan, either indicating the need for advising against surgery or for dealing with the aortic valve at the same time as the mitral valvotomy or later (see page 319).

Tricuspid regurgitation may accompany a mitral stenosis with right-sided enlargement and be functional in nature and is not in itself a contra indication Tricuspid stenosis if severe and accompanying mitral stenosis may require surgical treatment at the time of mitral valvotomy or a later date

Some features that are less favourable Atrial fibrillation, calcification of the valve associated tricuspid or aortic valve lesions or right-sided heart failure with a pulmonary artery pressure over 80 mm Hg do not contra indicate surgery but their presence makes the outlook less favourable Many patients with atrial fibrillation and with calcified valves have been operated on with success but both conditions carry a risk of post-operative embolism and patients with atrial fibrillation on the whole do not do as well as those with normal rhythm Pre-operative systemic embolism is not a contra indication to operation It is the stenosis which causes the embolisms and operation may well prevent further catastrophes In combined aortic and mitral disease clearly the most careful estimates must be made (See page 310) If the mitral stenosis is the predominant lesion minor degrees of aortic regurgitation or stenosis can be ignored The main surgical difficulty is where there is severe aortic stenosis Increasingly both valves are being operated on at the same operation or on separate occasions The same reasoning applies to tricuspid stenosis

Surgeons and cardiologists are now sufficiently pleased with the results of mitral valvotomy to accept many bad risks and most patients with mitral stenosis who have deteriorated should be assessed with a view to possible surgery

The contra indications to valvotomy Recent attacks of rheumatism and a raised sedimentation rate indicate the need for delaying surgery unless the presence of lung oedema demands urgent relief of the valve obstruction No longer is valvotomy withheld from patients under the age of 20 if the picture is one of tight stenosis with persistent deterioration surgery is indicated in eight patients of this age group operation has revealed a valve orifice of less than 1 cm All have done well with no evidence of rheumatic recrudescence Recurrence of symptoms after three to five years of relief is often an indication of a previous inadequate mitral valvotomy rather than re-stenosis due to rheumatism re-operation in such cases is indicated and can well be done by Logan's method (page 316)

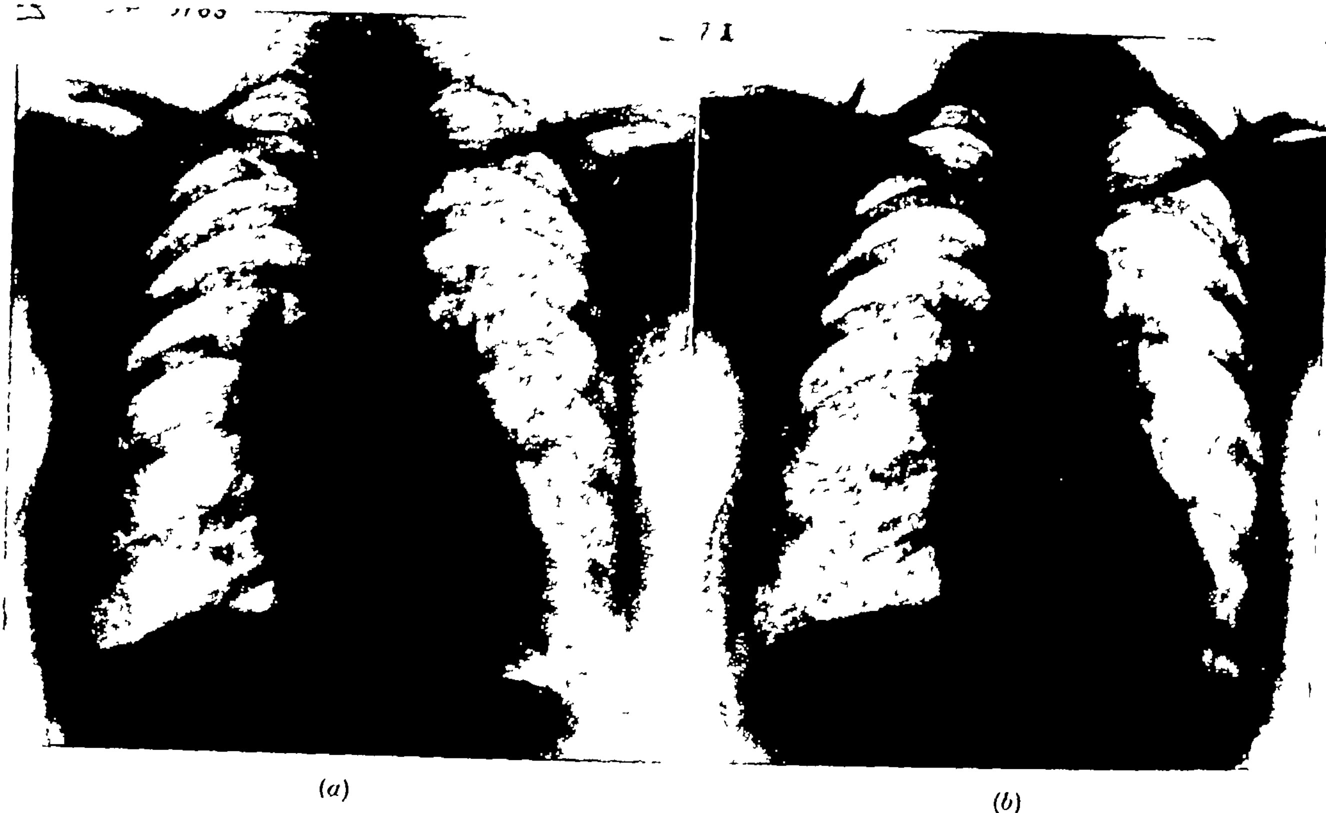
The operation

Pre medication and anaesthesia This has been discussed in Chapter 4 Adequate digitalization is the best method of damping down cardiac irregularities during operation Sedatives and anaesthetic drugs should be employed in small doses Pre-operative anxiety must be allayed as extra excitement may induce pulmonary oedema The patient should be brought to the operating theatre in a propped up position if that is the customary one he adopts in bed for sudden procumbency may precipitate oedema of the lungs After induction by pentothal the vocal cords are relaxed by small doses of curare so that rapid intubation can be achieved easily as the immediate delivery of oxygen is essential Anaesthesia is maintained by supplementing the oxygen with nitrous oxide and small doses of pethidine the minimum amount of relaxant drugs necessary to permit controlled respiration being given The anaesthesia is so maintained that at the close of the operation consciousness is regained

An intravenous dextrose drip is set up so that at any stage of the operation blood can be substituted if required Excessive transfusion is to be condemned in these patients with pulmonary hypertension but adequate replacement of blood loss is essential and it must always be remembered that thoracotomy in itself produces a tendency to post-operative

anaemia about the third–seventh day. If the blood pressure falls unduly at any stage of the operation, small doses of nor-adrenalin are run into the drip apparatus

The operation —The standard left postero-lateral thoracotomy with the patient lying in the right lateral position is the best approach (Fig. 4 1) This can be obtained through a fifth left interspace incision without rib resection if the chest wall is rigid a small segment of the fourth rib just in front of the angle of the ribs can be excised sub-periosteally to enable easy rib-spreading (See page 77) The lung is often plethoric and heavy and sometimes rivulets of oedema fluid can be seen under its visceral pleura The lung is retracted backwards by light pressure over a moist saline pad



(a) (b)

Fig 13 8

(a) Radiograph of patient before valvotomy

(b) Radiograph after valvotomy shows reduction in heart size, return of pulmonary segment to normal shape and decrease of lung vascularity

The pericardium is opened by a long vertical incision this may be placed in front of or behind the left phrenic nerve. If the atrial appendage, as seen through the intact pericardium is small, it is advantageous to place the incision behind the nerve, as such an approach allows a fuller exposure of the atrial wall and thus makes the placing of a purse-string suture (if such is necessary or used) in that structure easier

The lips of the pericardial incision are held apart by retracting sutures The heart is then examined thoroughly Typically, the pulmonary artery will be noted as grossly enlarged and rigid the left atrium will also be enlarged If there is significant mitral regurgitation, a systolic thrill may be felt The aorta should be palpated for a systolic thrill indicating the presence of an associated aortic stenosis If doubt exists as to the degree of aortic stenosis (should such be present) direct pressure readings can be taken from the left ventricle and the aorta to estimate the gradient present If this is high (40 mm Hg upwards) coincident aortic valvotomy might be indicated In the usual case of mitral stenosis, a diastolic thrill can often be felt at the apex of the left ventricle

The approach to the mitral valve Of the several possible routes there can be no doubt that most surgeons usually use the left atrial appendage the left superior pulmonary vein or the atrial wall may rarely have to be traversed to gain access if the appendage is shrunken fibrotic or much blocked by an organized mural thrombus Logan frequently combines an atrial with a ventricular approach where the valve is so calcified or fibrosed that instrumental valvotomy through the atrium is ineffective Under such conditions with the right finger in the left atrium he passes a small aortic dilator through a small incision in the left ventricle into the mitral orifice from below upwards Using the right index finger to place the dilator accurately in the valve the commissures of the valve can be rapidly split by his ingenious method We have found it to be excellent and use it frequently

For the sake of completeness it may be mentioned that the mitral valve can be dealt with through the right atrium when a septal defect is present The splitting of a stenosed mitral valve before the closure of an atrial septal defect through the right atrium was first achieved by Bailey when dealing with a patient suffering from the Lutembacher syndrome This surgeon (Bailey 1957) now prefers to operate on the mitral valve from the right side by an incision made in the inter atrial sulcus His full description of the operation is clear but indicates the need for great surgical expertise

The cardiotomy The major risk of mitral valvotomy is that of arterial embolism to the cerebral abdominal aortic and limb vessels This risk is commoner in patients with atrial fibrillation although the danger of embolism of calcified particles is present in patients in normal rhythm who have calcification of part of the mitral valve Before the appendage is opened the most careful examination of it is essential before clamp or sutures are applied If clot is present the surgeon is at once confronted with the problem of whether to employ temporary compression of both carotids or not Opinion is divided as to the value of this and I have not yet been able to decide myself on this point Bailey with a vast experience of mitral valve surgery is convinced of its value but some surgeons believe that after removal of the temporary occlusion of the vessels cerebral emboli can still develop and that even the short period of interruption by clamp or tapes drawn up in a Rumel tourniquet can cause cerebral damage as the result of the ischaemia and the post operative development of arterial spasm after the injury following the clamping of the vessel itself * If there is obvious clot felt in the appendage and I anticipate a difficult atrial entry I employ temporary clamping of the innominate and left carotid arteries opposition to this method has been expressed by Glover (1955) who believes that it is dangerous and prefers to rely on a very careful preparation of the clotted appendage to prevent embolisms His rate of embolism is certainly very low Digital pressure of the carotid vessels by the anaesthetist during atrial and valve manipulations does not commend itself as being very effective Under no conditions is it permissible to keep the carotid vessels compressed for more than two minutes The method of dealing with atrial thrombi by careful handling is probably more effective than vascular compression

Some surgeons employ an encircling purse-string suture placed in the myocardium at the base of the atrial appendage such a suture is said to act as a safeguard against atrial wall tears It is certainly an essential step if the atrial appendage is shrunken and fibrotic Personally I rarely employ it and have had no deaths from atrial bleeding in 400 valvotomies except in one patient in whom the superior pulmonary vein was used in a patient with a large wall thrombus in the left atrium Whether a suture is used or not the appendage

* R Barrett in 200 consecutive valvotomies done with temporary occlusion has had no cerebral emboli

is lightly held in a mitral clamp (Fig 13 9) The tip of the appendage is opened by scalpel and scissor dissection to a size that will readily admit the index finger, it is unwise to remove any atrial tissue at this stage The finger is then inserted into the atrial chamber for digital examination of the valve



(*a*) (*b*)



(*c*) (*d*)

Fig 13 9—The approach to the mitral valve

(*a*) The pericardium has been exposed and the phrenic nerve is shown
(*b*) The pericardium has been opened anterior to the phrenic nerve and held away by suture retractors the atrial appendage has been lightly clamped and overlies a grossly distended pulmonary artery
(*c*) The finger is exploring the mitral valve through an atrial incision
(*d*) The incision in the atrial appendage has been closed by interrupted silk (000 sutures)

If clot is known to be present before the actual cardiotomy, different types may be encountered Many thickened appendages have mural, organized thrombi which are obvious as soon as the appendage is incised Such well-organized clots need not be disturbed but saline should be used under pressure to irrigate the wound before the clamp is opened, as deliberate attempts to dissect them out may cause a loosening of clot Before the

finger is introduced the clamp is temporarily released to allow any loose clot to gush out This manœuvre may have to be repeated The problem of large clots up to the state of local thrombi will be discussed later To obtain adequate opening of the atrial appendage columnae carneae may require incision in the line of the incision

Exploration of the valve The whole valve area requires rapid examination In the usual case the mitral valve opening is circular about 1 cm in diameter and sited in the centre of the fused valve cusps With the patient in the right lateral position the aortic cusp lies to the right and the mural one to the left (Fig 13 10) In mitral stenosis the extremities are fused to form commissures The antero-lateral one is at the eleven o clock position the postero-medial one being at five o clock The essence of

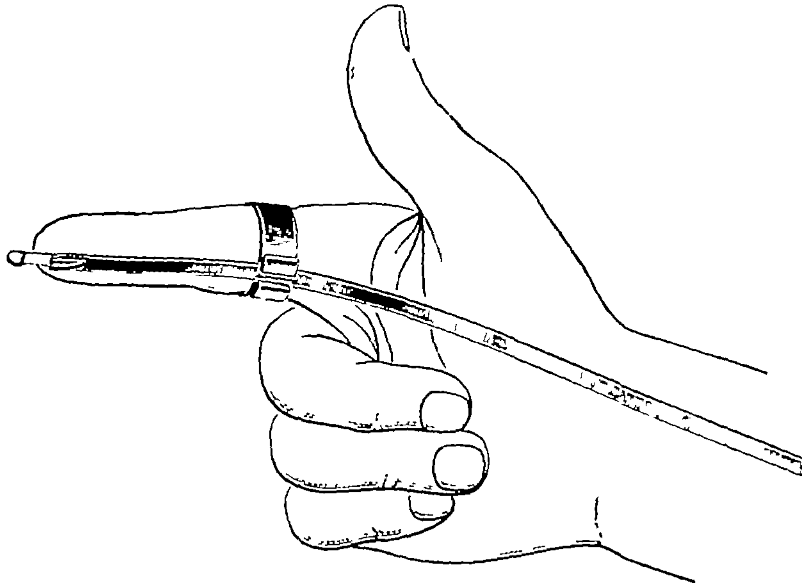


FIG 13 10 —The mitral valve (normal) from above

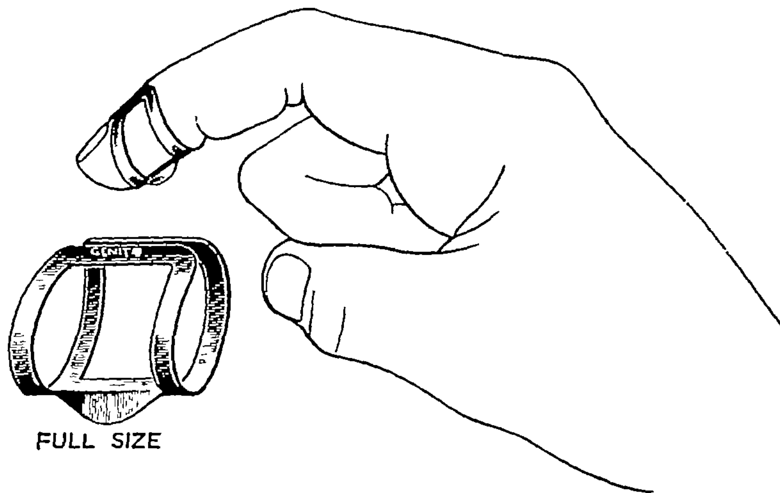
The photograph is taken in position to correspond with the state that would exist in a patient lying in the right lateral position. To the right is the convex aortic or septal cusp in apposition to the mural concave one

a good valvotomy is adequate splitting of both the commissures preferably to the annulus the valve cusp and the attachment of the ventricular papillary muscles to them must not be cut as incompetence would result The term commissurotomy (Bailey) is a more accurate and explanatory one than valvotomy Brock (1952) in describing the anatomy of the normal and diseased mitral valve has emphasized the importance of the need to free valves thoroughly at the commissures and has shown how this manœuvre allows the papillary muscles to function properly once more The critical areas of tendon insertion are at the junction of the horizontal and the lateral receding parts of the valve cusp In mitral stenosis the fusion of the valve cusps takes place largely at the two apposing critical areas so that in diastole the central opening is held closed as it is normally in systole In the typical case of stenosis the valve cusps are fused from the atrial ring up to and

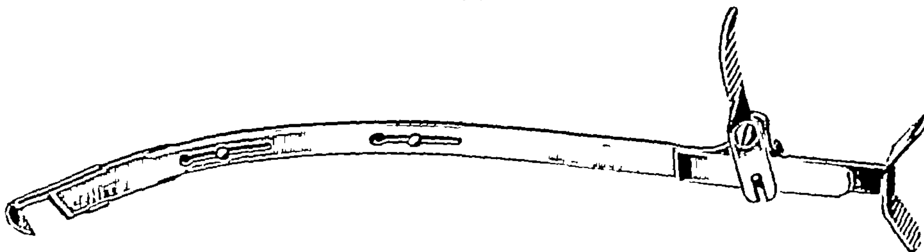
including the critical areas of tendon insertion The freeing of these adherent areas usually provides great relief to the obstructed left atrium and allows blood to flow freely to the ventricle without the onset of regurgitation.



(*a*)



(*b*)



(*c*)

Fig 13 11

(*a*) Brock's mitral knife
(*b*) Thompson's mitral knife
(*c*) Bailey's mitral knife Left—there is also one for the right of the postero medial commissure
(G U Mfg Co)

The inserted finger will detect the presence or absence of regurgitation Even with a moderately tight stenosis there may be a regurgitant jet, this will usually be in the

region of the postero-medial commissure the valvular opening in that region associated with a tightly fused antero-lateral commissure to produce the tear-drop shaped opening (Bailey) Such regurgitation can be relieved by a good antero lateral commissurotomy without any division of the postero medial one being attempted In fact further enlargement in that area could well increase the regurgitation

The valvotomy In ideal cases in which the rheumatic process has only involved the outer margins of the valves the cusps will feel supple and not thickened the finger slips into the valve orifice and the antero lateral cusp may be split with great ease With the palmar surface of the index finger the initial tear is augmented by several rapid movements of the finger so that the split extends out to the annulus of the atrio ventricular ring In such patients the valve opening can be enlarged to 3 cm or more without any regurgitation.

Frequently however the valvular orifice is extensively deformed with rigid thickened cusps and with extension of the chronic inflammatory process into the ring and into the chordae tendineae with shortening of the papillary muscles producing a funnel shaped atrial chamber Calcification in one or both cusps is sometimes present Unless a really adequate commissurotomy can be produced in these patients the results will be poor In some instances the deformity is so severe that the most thorough operation will not suffice to provide lasting relief Such valvular orifices for their real liberation will require division by a valvotome or by Dubost s or Logan s method which I use in most operations

Digital and instrumental valvotomies It is impossible in any large series of operations to obtain good results by digital methods only The use of the finger in combination with a valvotome should be frequent If moderate force with the finger will not initiate a good split the attempt must be abandoned at once and an instrument used The ideal instrument is one that allows both methods to be used consecutively without withdrawal of the instrument from the atrium A large choice is available and the surgeon must be familiar with one or two (Fig 13 10)

Originally I used the simple ring knife of Thompson but this is not always effective against a rigid inelastic commissure which is best opened by the use of a dilator

Whether an instrument is used or not the initial approach to the valve is the same The tip of the index finger is insinuated through the valvular orifice if the opening is very small this movement requires considerable force but the passage can always be achieved This is in no sense to be taken as supporting the idea of dilatation Usually the antero lateral commissure will split a little in these extreme cases although undoubtedly the orifice can be stretched to accept the finger Such a dilatation will never be effective and must be followed by a proper tear or cut of the commissure When the finger is through the valve its palmar surface exerts a constant firm pressure upwards on the antero-lateral commissure and by a series of movements the commissure is split well up to the annulus The orifice must not be blocked on each manœuvre for more than a few heart beats but this does not prevent several attacks to be made as the finger is bent back to the atrium between movements If a really satisfactory digital antero lateral commissurotomy has been achieved the finger is then rotated and the same separation of the postero medial commissure is attempted The best way to attempt this is to pass the finger down into the ventricle and then to press upwards on the inferior surface of the commissure Separation is never so easy as on the other commissure and should not be attempted with too great a force as the attachment of the chordae tendineae to the cusp in this area could be torn with the production of mitral regurgitation

In over 70 per cent of cases a valvotome or a dilator is used, after their use, the tear can usually be enlarged to the annulus by finger. The index finger is withdrawn and the atrial clamp applied if a ring type of valvotome is to be used. If Bailey's knife is to be used, this can be introduced along the palmar surface of the finger into the atrium. It is introduced with the blade shut and is then guided into the valve orifice so that it can be accurately placed. The guillotine is then opened so that the blade lies accurately in the line of the commissure which is divided by closing the blade. The valvotome is then withdrawn to the atrium and the finger continues to enlarge the tear so initiated. If progress is not satisfactory, the knife may be opened to continue the section.

Thompson's ring knife or the one devised by Dogliotti is slipped on to the index finger so that the cutting edge is on its palmar surface just above the crease of the inter-phalangeal



FIG 13 12—Logan's operation

The right index finger is in the right atrium ready to guide the dilator, which has been introduced through a small incision in the tip of the left ventricle, into the stenosed mitral orifice. When the blades of the instrument are in the correct site they will be opened to split both commissures

joint. With a steady sawing movement it cuts into the commissure, the final separation being achieved by digital fracture, when the blade is being used on the postero-medial commissure, the blade lies over the nail of the finger. Whenever this knife is used, two strong thread or silk sutures must be tied to the knife, as it could slip off into the ventricle.

Where there is heavy calcification of both cusps it is still possible in most instances to divide the antero-lateral commissure as complete circumferential calcification is rare. If no adequate split can be achieved in such patients, Logan's method of introducing through a small incision in the left ventricular wall an aortic dilator which can be guided accurately into position by the index finger already in the left atrium is of value. This method has an advantage over the Dubost (1955) method of applying a dilator to the valve through the atrial appendage as the finger within the valve is such a good guide.*

When the valve mobilization has been completed, the surgeon must always explore

* Increasingly I use Logan's method. This provides an excellent split of the postero-medial commissure

the sub valvular area as cross fusion of the chordae tendineae may not infrequently cause sub valvular stenosis and also prevent the correct movement of the valve *cusp* Such adherent papillary muscle can usually be separated with surprising ease by gentle massage with the finger When the valvotomy is completed, the atrial appendage clamp is re-applied as the finger is removed from the atrium part of the clamped-off appendage is excised and the opening closed by interrupted silk or thread sutures

The pericardial flap is sutured back in position but large gaps must be left to allow post-operative effusions to escape into the left pleural cavity

Post-operative complications In addition to those common to all intrathoracic operations such as post-operative effusion and atelectasis specific complications such as atrial fibrillation and embolisms may develop Atrial fibrillation is not a contra indication to operation if it develops post-operatively it is treated by digitalis if the pulse rate is fast If the fibrillation persists the effect of quinidine may be tried

Embolism is an undoubted danger and may be cerebral or to the lower end of the aorta the femoral vessels or the upper limb channels Constant watch should be kept on all the main vessels in the immediate post-operative period as embolectomy can be carried out with success in some patients in whom the obstruction has occurred

Post valvotomy syndrome In a few patients after operation and at varying periods pyrexia and severe sub-sternal pain may develop this may be due to blood clot in the pericardial sac causing a fibrous pericarditis If it is associated with joint pains and a raised B.S R it is probably due to reactivation of rheumatism and then bed rest and salicylates are required such re-activation is extremely rare

Mitral regurgitation

The pre-operative assessment of mitral incompetence is not always simple A loud mitral systolic murmur without a thrill with diminished accentuation of the apical first sound without the characteristic snap typically heard in the presence of stenosis is suggestive of gross incompetence The suspicion is aggravated if the left ventricle is enlarged and the left atrium shows real systolic expansion in the antero-posterior view when the heart is screened radiologically but mitral stenosis of a pure type may well be associated with systolic expansion of the left auricle especially when seen only in the oblique position The certain diagnosis of the state of the mitral valve in some patients can only be detected by the exploring finger of the surgeon

As indicated in the section on mitral stenosis some regurgitation almost invariably in the region of the postero medial commissure can be corrected by a good division of the antero lateral commissure as this can restore valve movement the following remarks refer to gross mitral incompetence rather than that associated with what is primarily a mitral stenosis

Surgical attempts to relieve mitral regurgitation

Attempts to relieve this grave condition by the introduction of pericardial flap or plastic baffles have not gained much support The reduction of the size of the dilated annulus by a circumferential suture as advocated by Davila (1955) and his colleagues has provided better results The use of open surgery by Lillehei (1958) using total cardiac by pass seems at last to provide a scientific operation likely to succeed The left atrium is approached through the right pleural cavity ideally the regurgitation is corrected by using heavy silk sutures to draw together the annulus tissue (not the valve cusp) in the area of incompetence if there is deficiency of valve tissue at the edge of the cusp a portion

of compressed polyvinyl sponge is sutured to the valve edge to facilitate coaptation of the two cusps

THE SURGERY OF THE AORTIC VALVE

There can be no doubt that the surgery of this valve for the relief of stenosis or regurgitation has not achieved the support given by physicians to operations on the mitral valve, but large series of operations have been reported by Bailey (1955) and Brock (1957) Two difficulties predominate

(1) Assessment of prognosis in this disease is difficult The detection of the disease in symptomless patients is easy in most of these once symptoms have developed the prognosis of rapid deterioration can usually be surmised, but such symptoms may not arise for years Once deterioration has started, it is rapid and the risks of surgery are increased

(2) The state of the valve in many patients with symptoms is such that surgical relief is difficult, the chief technical problem is heavy calcification of the valves Attempts to divide the commissures of such valves, even on autopsy material, may fail but in others a fibrous commissure surrounded by calcium may split well



FIG 13 13 —A stenosed bicuspid aortic valve which has been well divided along the line of the commissures by a bi radiate dilator inserted through the left ventricle in the centre of the valve opening the original small orifice can be seen

This patient of 38 had gross left ventricular hypertrophy the actual valvotomy was carried out with no difficulty and he regained consciousness and seemed well until sudden death, almost certainly from ventricular fibrillation, occurred some hours later

Pathology of aortic valve stenosis

Apart from a rare congenital condition of true stenosis or *fibro-elastosis, the overwhelm*ing cause of mitral obstruction is rheumatic disease The aortic stenoses, however, are

more complex since the obstruction may be caused by true congenital stenosis (diaphragmatic in type) at or below the valve (sub aortic stenosis) by rheumatic disease syphilis, arterio-sclerosis or bacterial endocarditis The congenital condition of bicuspid valves is not uncommon in coarctation of the aorta when enlargement of the left ventricle may lead to regurgitation it is possible that bicuspid valves are more prone to rheumatic disease than the usual tricuspid ones and certainly such valves may become the seat of acquired stenosis This means that the surgeon cannot always expect three cusps to be present and he might damage a cusp with the production of severe regurgitation This in itself is in a way a further support in favour of the use of Bailey s trans aortic approach or of open cardiac surgery as this allows a careful examination of the valve which is not possible by the blind trans ventricular approach A dilator with only two blades can enable a good commissurotomy to be carried out as shown in Fig 13 13 A rare type of congenital aortic stenosis provides a megaphone type of valve with no demonstrable cusps and with a typical post-stenotic dilatation of the aorta Aortic stenosis is usually rheumatic and calcification is a frequent sequel to the fibrous union of the three commissures between the cusps Although many calcified valves have been opened by operation some stenotic valves exist in which it appears that valvotomy would have been impossible if routine post-mortem material can be taken as being typical In syphilis the associated involvement of the aorta and the surrounding tissues means that incompetence frequently accompanies stenosis

The selection of patients

Bailey has undoubtedly the largest experience of aortic valvotomy and up to the middle of 1955 in five years he operated on 155 patients by cardiotomy through the left ventricle and 51 by the trans aortic method After ventricular operations the mortality rate was 28 per cent but has fallen to 12 per cent after trans aortic operations In both groups at the time of aortic operations a considerable number of coincident operations on the mitral valve for the relief of stenosis was carried out and the mortality group in both types of surgical approach was far lower e g in 87 trans ventricular operations plus mitral valvotomy the mortality rate was 18 per cent and in 20 patients operated on by the trans aortic approach an associated mitral stenosis was relieved simultaneously with a mortality rate of only 5 per cent This when considered superficially seems paradoxical the real explanation however is that in patients with stenosis of both valves the mitral obstruction prevents the left ventricle from the effects of excessive filling These results seem to indicate therefore that a high mortality rate is likely to occur in pure aortic stenosis with considerable left ventricular strain If progress in aortic valve surgery is to be made the difficult decision will always be to select patients who have not too extreme degrees of such ventricular embarrassment these patients therefore will be those with minimal *symptoms* *Against* advising such patients to be operated upon must be put the mortality rate which is from 5–10 per cent in patients who are not too advanced and the unassessed follow up results and the difficulty in assessing prognosis as some of the patients who have been diagnosed at 25 or 30 live into the 60 s Bailey has attempted to deal with this by placing patients in four groups

Class I Physical signs of aortic stenosis with no symptoms
Class II Those with a limited ability to engage in vigorous activity
Class III Those with dizziness or angina on effort and with evidence of myocardial failure which can be relieved by medical measures Their prognosis is poor

Class IV Those in grave trouble with congestive heart failure, a very large heart and often a gallop rhythm

Classes II and III have provided the main bulk of Bailey's patients Class IV are accepted as very grave risks if all concerned understand the full position In 1956 his series of operations had reached 287

Many physicians are still conservative about aortic stenosis surgery but in any large series of mitral valvotomies an appreciable number of patients will have aortic stenosis The effects and severity of this can be estimated clinically (type of pulse and the state and size of the left ventricle) accurate information, however, can be obtained at the time of the mitral valvotomy by taking direct pressure readings by the mercury manometer in the left ventricle and in the aorta so that an accurate estimate of the gradient across the valve can be made It can be said that no aortic valvotomy should be performed without such information having been obtained If the gradient is 50 mm Hg or over, valvotomy is indicated Such pressures can be taken pre-operatively, see below

Trans-aortic or ventricular approach ?

Bailey's account in his book *The Surgery of the Heart* should be read by all interested in the problem of aortic stenosis It is significant that after using the ventricular approach for 155 operations Bailey has now changed to the trans-aortic one, except in some patients who require aortic and mitral valvotomy at the same operation and in whom the mitral lesion is clearly the predominant one

The dangers of incising and manipulating the left ventricular muscles are (i) the great tendency for ventricular fibrillation to develop at the time of or after operation , (ii) the difficulty of closure of the incision when the muscle is friable , (iii) the inability to palpate digitally the aortic valve , this fails to allow the surgeon to know whether he is dealing with a tricuspid or bicuspid valve (Fig 13 13) and therefore hampers him in the decision as to whether he should employ a tri-radiate or bi-radiate dilator and quite excludes the use of a knife-edged valvotome For this reason, Bailey now states with conviction that he prefers the trans-aortic approach Brock (1957) published excellent results from trans-ventricular operations The future of aortic valve surgery will undoubtedly be by open, visual methods, which I use routinely

The operation—some technical points

The pre-operative care of these patients is important and as full studies as possible must be made to estimate the state of the cardiac muscle and of the other valves, as these may require simultaneous correction of stenosis A long period of medical treatment including rest and digitalis may be necessary Pre-operative pressures in the left ventricle can be obtained by percutaneous puncture (Brock) or via a catheter passed through a cannula introduced into the left atrium through a bronchoscope, or by direct puncture.

The trans-ventricular approach One advantage of this approach is that it is simple and does not involve transverse section of the sternum or opening of both pleural cavities and allows an associated mitral stenosis to be dealt with more easily If the mitral stenosis is the predominant lesion, this approach is favoured The lateral approach will appeal to most surgeons though an anterior one probably gives a better view of the aorta itself With the patient lying on the right side, the fourth or fifth space is opened right up to the edge of the sternum, with division of the internal mammary vessels The pericardium is opened widely by a vertical incision in front of the phrenic nerve The aorta and left ventricle are

examined visually and digitally to detect such conditions as calcification of the aortic valve area to confirm the presence of a systolic thrill or of a mid-diastolic thrill if there is coincident mitral stenosis Pressures are taken in the left ventricle and the aorta by a needle connected to a mercury manometer

The site for the cardiotomy must be chosen with care to avoid damage to important coronary vessel branches The best site is usually about 2–3 cm above the apex as the muscle here is less friable than at higher sites and because there is less risk of damaging important vessels A purse-string suture is inserted at the chosen site and the ends of this are incorporated in a Rumel snare (Fig 13 14) Within the circle of the suture a small incision is made down to the endocardium and an olivary tipped guide is thrust into the ventricular chamber and up into and through the aortic valve so that it can be palpated by the fingers of the left hand placed on the aorta close to the valve level The ventricular incision is then enlarged so that it will accept the larger dilating instrument which is then passed These and succeeding manoeuvres to be described may be difficult and hazardous Once the dilator is engaged in the valve the handles of the instrument are squeezed to produce the commissurotomy The instrument's head should be expanded three times in three different places to split each of the three commissures Even with considerable force the valve if calcified may fail to be opened adequately and this is one of the defects of the approach as finger palpation cannot be used to confirm the efficacy or otherwise of the operative splitting of the commissures



FIG 13 14—Rumel's cardiac snare

The dilator is withdrawn and the purse-string suture tightened haemostasis is achieved by this and by the use of digital pressure upon the ventricular wound, which is then sutured These sutures will cut through the muscle far more easily than those used for the closure of a right ventricular wound carried out for pulmonary valvotomy and constant care is taken to avoid this A piece of gel foam is sutured over the incision

Ventricular fibrillation may occur at any stage If it develops while the dilator is in place the valve must be opened rapidly The fibrillation demands rapid treatment by the defibrillator shock machine so that the arrested heart can then be massaged (see page 72)

The trans-aortic approach of Bailey With the patient supine a large curved incision reaches from one axilla to the other passing well below the breasts The breasts and the pectoral muscles are freed upwards and retracted there so that access to both pleural cavities can be made through the third right and the fourth left interspaces After ligation of both internal mammary arteries and division of each fourth costal cartilage the sternum is divided transversely and widely retracted together with the ribs above and below the transpleural incisions by a heavy retractor of the Finochietto type

A large flap of pericardium is removed from over the left side of the heart as this will be required to make a pouch which is later sutured on to the lip of an incision in the aortic wall to enable manœuvres to be performed within the well so created An incision 4 cm in length is made in the centre of the stretched out graft and well to the periphery of the patch of pericardium a purse string suture is sewn in The suture will later be drawn

up into a Rumel snare so that a finger and instruments can be held snugly by the graft after it has been stitched into an incision in the aorta when the tourniquet has been drawn taut

A portion of the anterior wall of the aorta about 4 cm above the aortic valve is pinched up by a Satinsky clamp a 4 cm. incision is made into this part of the aortic wall and the central opening in the graft is sutured to the two lips of this wound so that the smooth layer of the pericardium forms the inner wall of the " well " Through the artificial appendage or diverticulum of the aorta so made, the necessary manipulations with the finger or instruments can be carried out on the aortic valve, after the purse-string suture has been tightened to prevent loss of blood

The valve is examined digitally and the aortic stenotic opening is triangular or a slit, an accurate estimate of the degree of stenosis and the extent of the calcification disclosed, gross calcification may prevent any attempt at relief as severe aortic regurgitation will follow unless the valve leaflets can be mobilized properly by splitting the commissures digitally or with instruments In one half of the cases recorded by Bailey, commissurotomy has been possible by finger fracture, the others have required instrumental division of commissures and for this a special instrument, less heavy than the trans-ventricular one, has been devised or a special guillotine knife may be required Bailey's account gives full details of the type of valve encountered and the method by which they should be handled

At the close of the surgery on the aortic valve the finger is withdrawn into the " well " and the Satinsky clamp is re-applied The graft is then removed and the aortic wound carefully sutured by a continuous everting mattress suture

The chest is closed on both sides after the two sternal fragments have been approximated by stainless steel sutures placed through appropriate drill holes the pleural cavities are drained by temporary water-sealed drains

The account given of these procedures should be regarded as fragmentary and Bailey's work consulted for details, which are meticulously explained

Brock (1957) and Logan (1954) have made notable contributions to this subject, which is engaging the attention of many surgeons and many aortic valvotomies are being done

The approach to associated aortic and mitral valve stenosis Bailey states that in his series of rheumatic aortic stenoses, in nearly 50 per cent of patients there was a co-existent mitral obstruction If surgery is being offered to such patients and both valves are seriously affected, it would seem wise to correct both obstructions at the same operation and Bailey has often done so If the mitral stenosis is predominant, many surgeons might prefer to attack the mitral valve only if direct pressure readings on the left ventricle and the aorta showed the gradient across the aortic valve not to exceed 40 mm Hg

In cases of doubt it is safer to defer operation on the aortic valve till a later date, as the mitral valve surgery may cause a hypotension that does not improve rapidly enough to permit safe exploration of the left ventricle

If, however, the operations are to be carried out at the same time, it is probably better to do the mitral surgery first if the plan has been to attack the aortic valve through the left ventricle The subject of simultaneous valvotomies on the mitral, aortic and also the tricuspid valves is under active discussion at the time of writing

Operations on the aortic valve with the cardiac by-pass

Lillehei and his colleagues (1958) favour open aortic surgery under conditions of extra-corporeal circulation because they believe that the risk of ventricular fibrillation is less and that more safe operating time is available In their operations they prefer to operate on a heart that has not been artificially arrested by potassium or acetyl choline and prefer

to maintain the nutrition of the myocardium by retro-perfusion of the coronary sinus with arterialized blood which can be obtained from a separate tube attached to the system of tubing leading from the arterial pump to the subclavian or femoral artery Other surgeons doing these operations under by pass conditions consider this to be unnecessary The correc tion of aortic regurgitation as well as of stenosis has been achieved by using by pass methods

Open aortic valvotomy under hypothermia

Increasingly open valvotomy will in the future be done with the use of extra corporeal circulation initiated as far as I know by Lillehei because the actual performance of valvotomy under vision through an incision in the ascending aorta is easily achieved in 2–4 minutes hypothermia has great attractions Interruption of the cardiac inflow and outflow with the patient at a temperature of 32° provides operating conditions of reasonable safety and may be safer than total by pass A bilateral anterior thoracotomy through the third interspace with transverse division of the sternum enables the pericardium to be widely opened with the caval vessels and the lung roots occluded by tapes a few seconds are allowed to elapse until the carotid pulses have disappeared Before the occlusion four sutures have been placed, two on each side and one each at the top and bottom of the proposed line of the aortic wall incision As soon as the carotid pulses have gone a large clamp is placed across the pulmonary artery and the aorta The aorta is then incised, blood sucked out of its lumen and the commissures of the aortic valve divided with strong scissors In the congenital type of case the commissure development is defective and often two incisions only are made in it A finger is then passed into the left ventricle to exclude sub-aortic stenosis and to make sure the valve is widely opened If a sub-aortic diaphragm is present part of it is cut away

The tapes around the caval vessels and the lung roots are released after the previously placed stay sutures in the aortic wall have been lifted up With the release of the circulation into the heart blood rapidly fills the left ventricle and the aorta Since the aortic incision is at the highest level blood with air escapes from the wound thus flow is allowed freely before a spoon shaped fine-toothed clamp of the Potts type is used to close the aortic wound as soon as this has been done the clamp occluding the pulmonary artery and the aorta is released By this method the risk of air embolism has been greatly diminished and has not been a problem in our cases The incision in the aortic wall is then closed by suturing its lips as it is held in the toothed clamp The operation is concluded as in other open cardiac operations

Aortic regurgitation

Direct attempts in the valvular area itself to diminish regurgitation by pericardial flaps or baffles have failed Hufnagel (1954 1955) has devised a plastic ball valve which is inserted into the descending aorta below the subclavian artery This relieves part of the strain on the left ventricle by raising the diastolic pressure

Lillehei (1958) has successfully corrected regurgitation by open aortic surgery using the bubble oxygenator ingeniously he converts the valve cusps into a bicuspid orifice to correct the incompetence If because of shrinkage or loss of valve substance regurgitation is still likely compressed polyvinyl sponge is sutured to the valve edges to enable coaptation to take place

THE SURGERY OF TRICUSPID STENOSIS

Isolated rheumatic tricuspid stenosis is uncommon but is not rare in association with mitral stenosis Wood (1954) writing on the incidence of rheumatic involvement of the different valves

gives figures as mitral 80 per cent, aortic 48 per cent, tricuspid 12 per cent and pulmonary 5 per cent When tricuspid stenosis produces its own signs and symptoms the valve orifice may become so small that a cigarette would not fill its lumen

As expected, severe obstruction to the outflow from the right atrium causes ascites, oedema, distended neck veins and a tender enlarged liver unless the mitral valve is also affected, orthopnoea will not be an early feature because of the absence of pulmonary hypertension The oedema and liver enlargement often persist after adequate medical treatment for congestive heart failure A curious bronze discoloration of the skin of the face may be present Pulsation in the distended neck veins is accompanied by giant "*a*" waves, a diastolic murmur is heard to the left of the lower border of the sternum but may be heard on the right side This murmur may be difficult or impossible to isolate from murmurs due to other coincident valve lesions Radiological examination will disclose gross enlargement of the right atrium, pulmonary hypertension will be absent unless the mitral valve is also diseased In the absence of atrial fibrillation (which is often present) the electrocardiograph may show the increased *P* wave of right atrial hypertrophy in lead II The most satisfactory method of establishing the diagnosis is by the cardiac catheter which demonstrates the atrial diastolic pressure to be well above that found in the right ventricle Accounts of surgical relief have been given, amongst others, by Bailey (1955), O'Neill (1954) and Chesterman (1955)

The approach to the valve is through a right-sided anterior approach to the right atrium and the principles of valvotomy are the same as those for mitral stenosis If the appendage is blown out, the access to the valve may have to be made through the atrial wall tissue in which case a purse-string suture mounted on a Rumel snare is employed If the mitral or/and aortic valves have to be attacked at the same operation, the wide opening of both pleural cavities with a transverse division of the sternum is employed Digital fracture is possible but may require help from one of the valvotomes used in mitral stenosis fortunately, this valve rarely calcifies

CARDIAC INJURIES AND WOUNDS

Perforating, penetrating and crush injuries of the heart though rare in civilian practice require consideration In explanation it must be stated that a penetrating wound differs from a perforating one in that in the former a foreign body lodges in the pericardium, the heart muscle or within the chambers of the heart A number of cardiac wounds survive the initial injury, Wood and Nicholson (1945) studied 25 survivors at a base hospital out of 1,640 consecutive chest wounds and d'Abreu, Litchfield and Hodson had 10 in 1,000 patients under similar conditions Harken (1946) not only indicates that many soldiers wounded by missiles lodging in or near the heart and great vessels survive but in an astonishing series of 134 patients operated on for the removal of such missiles there were no deaths, of these 134, 56 foreign bodies were removed from within or on the heart, of which 13 were taken out of a chamber of the heart itself

Clinical features of wounds of the pericardium and heart

In those who survive the initial gun-shot or stab wound the subsequent course may be dramatic or quite uneventful, it was not unusual in the last war to see symptomless, well soldiers with intracardiac foreign bodies present who at no time after the initial wounding presented symptoms or signs that caused the least degree of anxiety In others, however, the effects of cardiac tamponade were obvious at an early stage Tamponade depends on two factors firstly with small wounds, of the ventricles especially, blood leaks out during systole with a steady increase in intrapericardial pressure, secondly the heart may be embarrassed by a pericardial effusion which forms in response to the irritating effect of blood in the sac and occasionally to the presence of a foreign body With increasing intrapericardial pressure pallor, cyanosis and a fall in the systemic blood pressure are associated

with a feeble pulse and cold limbs The heart beat on palpation is quiet Unconsciousness may result from cerebral anoxaemia The neck veins show a raised pressure but are not conspicuously obvious nor do they pulsate in the early stages as they have not had time to enlarge as in heart failure or constrictive pericarditis the lower blood pressure and reduced cardiac output place the coronary blood supply to the heart itself in danger

The radiological appearances may show an enlarged cardiac shadow but this is not so obvious as in more slowly enlarging pericardial effusions which have time to distend the rigid sac

Treatment The traditional advice that wounds of the heart with tamponade require urgent surgical treatment is now regarded as questionable De Bakey and his colleagues from Baylor University have done much to indicate that major surgery is probably indicated in only 25 per cent of cases and that pericardial aspiration for relief of tamponade followed by careful observation for signs of deterioration will give much lower mortality rates than hurried surgery In 67 patients with cardiac wounds 28 were treated conservatively and open surgery in 14 The death rate was five times higher in the operation group than in those treated by aspiration Clearly the patients subjected to surgery were the iller ones but it was noted that in four of the seven who survived surgery and pericardiotomy the cardiac laceration had already become sealed off completely

If the condition deteriorates under conservative management surgery is indicated The pericardial sac is explored through the wound track if this is near to the heart or by a more formal approach The exposure should be wide enough to allow a hand to be passed freely into the pericardial sac beneath the apex of the heart

When the tense pericardial sac has been opened bloodstained fluid and clot may be rapidly extruded to be followed by true cardiac bleeding if the wound is in the ventricular wall the bleeding can be arrested by finger pressure as readily as in a direct operation such as Brock s pulmonary valvulotomy Sutures are passed through the heart muscle beneath the finger and then tied In the rare instance of a wound in one of the auricles finger pressure is not effective and the wall of the auricle must be seized in a clamp underneath which mattress sutures are placed

Removal of foreign bodies

Many patients have survived the first and second Great World Wars with metallic bodies embedded in the heart and apart from their removal in the early stage of treatment most surgeons would be loth to advise surgery removal Complications however do follow especially if the metal is in or near the pericardial sac Recurrent bouts of pericarditis with fever pain and malaise and evidence of effusion are indications for removal which in this site is neither dangerous nor difficult Foreign bodies may migrate either from the heart itself or from the great vessels Such migration may be the source of great puzzlement unless the phenomenon is remembered * A full account has been given by Barrett (1950) who also describes migratory foreign bodies that have entered the circulation by other than cardiac routes and lists an astonishing variety of material that has circulated He indicates that a foreign body lodged in the cardio vascular system is always a potential danger to life Those that lodge in the pulmonary vessels or systemic vessels should be removed Cardiac foreign bodies are clearly more dangerous when lodged *within the heart* chambers and provide a special difficulty to the surgeon he should probably remove them

* In the first instance I saw I had opened the right chest for the removal of a foreign body in the right lung At the exploration no trace of this fragment could be felt a portable radiograph taken in the theatre showed the metal to have *migrated from the right pulmonary* artery to the left

If any surgeon embarks on these operations the writings of Harken (1946) are available for study

Clinical features and treatment of contusions of the heart

Severe contusions of the heart may follow crushing injuries that leave the chest cage intact The characteristic cause is the impact of the steering wheel on the lower sternum in a head-on car collision accident, though this is not a common accident in Britain because of the type of car construction The severe effects of such a contusion may not be obvious for some days, though occasionally death follows instantly from violent rupture of the heart or aorta or ventricular fibrillation Quite exceptionally a haemo-pericardium may follow

In the more usual train of events cardiac bruising may be followed by complaints of weakness and easy fatigue some days or weeks after the accident , in the elderly subjects symptoms of coronary thrombosis may supervene If arterial damage has followed this may lead to infarction and a later cardiac aneurysm Because of these possible disagreeable sequels suspected cardiac contusion should be treated by bed rest for some six weeks with a carefully supervised convalescence

CARDIAC ISCHAEMIA

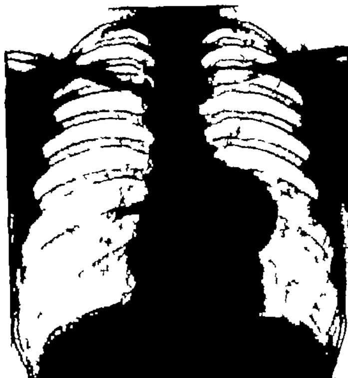
It is disappointing to have to report that many and determined efforts to re-vascularize the heart suffering from severe coronary artery insufficiency have not achieved success sufficiently obvious to convince most surgeons that such operations are worth employing Most of these operations have centred round efforts to graft living muscle, omentum or lung to the heart in the hope of establishing additional blood supply to the cardiac muscle Nor have the ingenious attempts of Beck, who anastomoses branches of the aorta to the coronary vein after distal ligation of the coronary sinus, been much used by others Vineberg has attempted to give help to the ischaemic heart muscle by implanting the internal mammary artery into it

Occasionally severe crippling pain may be relieved by sympathectomy operations in which the stellate ganglion and the upper four thoracic ganglia are resected

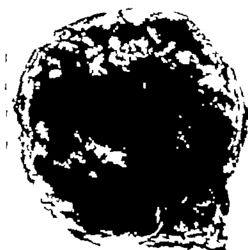
TUMOURS AND CYSTS OF THE HEART AND PERICARDIUM

Secondary tumours, usually bronchiogenic, are much commoner than primary ones, producing in the late stages a blood-stained effusion Primary tumours (fibroma, lipoma, mesothelioma and sarcoma) have been described in the pericardium , pericardial cysts have been excised and these usually accompany a defect of that sac (Sellors) , teratoid tumours and foregut reduplications affecting the pericardium are seen occasionally (Fig 13 15) Cardiac tumours are usually metastatic and commoner on the right than left side , primary ones, in addition to those mentioned as involving the pericardium may be rhabdomyoma, leiomyoma, sarcoma or hydatid cysts A full clinical and pathological description of myxoma of the left atrium, of which 77 have been described in the literature, has been given by McAllen (1950) A large myxoma of the left atrium has been removed by Crafoord (1955) the patient was on full extra-corporeal circulation for thirty minutes while the left atrium was widely opened with the left ventricle compressed below the mitral valve to

prevent embolism recovery has been complete Scannell (1955) had a similar success in Boston The condition was diagnosed pre-operatively by selective angiocardiography Chin and Ross (1957) have described the successful management of a myxoma discovered during a proposed routine mitral valvotomy through the left atrium they abandoned the idea of attempting removal at that time and some months later re-operated under hypothermia through the right atrium followed by an incision through the atrial septum as in the operation for closure of an atrial septal defect The result was excellent Beck has



(a)



(b)

Fig 13 13

(a) Radiograph of the chest of a man of *0 who complained of pain in the left chest.

(b) Photograph of intrapericardial cyst removed from this patient

The cyst, which had the macroscopic and microscopic appearance of a bronchial cyst, received a blood supply from the left pulmonary artery (intrapericardial portion) and was connected by a bronchial tube with the tracheal bifurcation.

successfully removed a benign tumour of the left ventricle which had a calcified shell and contained frothy like material rich in fat Fig 13 17 shows a tumour removed from the wall of the left ventricle (d Abreu 1950) Bailey in his book has discussed in detail the removal of tumours from the left atrium by open and closed cardiac surgery

ANEURYSMS OF THE GREAT VESSELS

The briefest survey of the work of Bahnson (1955) and de Bakey (1955) would show that formidable aneurysms of the aorta have been removed with or without the use of human or plastic homografts for the restoration of vascular channels The chief indications for surgery are the relief of pain and pressure symptoms produced by the vascular enlargements and the prolongation of life The palliative treatment of aneurysms by intrasaccular

A full account of intrapericardial cysts has been given by Dabbs and others (1957)

wiring (Colt, 1903, 1948) or by external splintage provided by encircling sheets of a fibrous tissue producer such as cellophane have become obsolete and the future clearly lies with excisional surgery

Of the two types, fusiform or saccular, the latter represents the true aneurysm as the other is a stage of enlargement in a syphilitic aorta , the latter carries incidentally a better prognosis though this depends usually on the amount of aortic regurgitation that accompanies it

Aneurysms are commonest in the ascending aorta and the arch , both may simulate inoperable bronchial carcinoma, though this is far more likely with the arch lesions The aneurysm of the ascending aorta may be large enough to compress the superior vena cava leading to distension of the veins of the head and neck, as in superior vena cava obstruction resulting from a bronchial carcinoma that has spread to the mediastinum the detection



Fig 13 16



Fig 13 17

Fig 13 16 —Teratoid tumour of the pericardium
A new born infant (*Brit J Surg*)

Fig 13 17 —Radiograph of the chest of a woman with a hydatid cyst in the wall of the left ventricle
This cyst was removed (*Brit J Surg*)

of a systolic murmur associated with a thrill and the positive Wasserman reaction will help in the diagnosis On radiological screening pulsation in the aneurysm is more likely to be forceful expansile and definite here than in saccular aneurysms of the arch

Aneurysm of the arch produces important signs and symptoms because of pressure on the left bronchus, the left recurrent laryngeal nerve and the oesophagus , involvement of the sympathetic nerve chain may give a Horner's syndrome. Such pressure signs and symptoms are often present in bronchial carcinoma that has invaded or compressed the structures mentioned and care in the differential diagnosis is necessary , quite a number of these patients are referred to thoracic surgical clinics as bronchial neoplasms because of the collapse of the left lung and the hoarse voice It is always important to remember that many saccular aneurysms on radiological screening do not show a characteristic expansile pulsation nor can reliance be placed on the expectancy that all aneurysms of the arch

give the signs of the tracheal tug Angiocardiography is of value in the differential diagnosis of thoracic aneurysm (p 344)

Most aneurysms of the thoracic aorta are syphilitic as opposed to the athero-sclerotic involvements of the abdominal aorta they therefore occur in a younger age group and are more likely to be saccular (Fig 13 18) Fusiform arterio-sclerotic aneurysms do occur but rarely cause symptoms demanding surgical treatment unless they give rise to dissecting aneurysms which here as in the abdomen are sometimes amenable to treatment (de Bakey, 1955) In addition to berry aneurysms on the aortic origins of intercostal arteries aneurysms



Fig 13 18.—Saccular aneurysm in a man of 48 with characteristic back pain. An ideal indication for surgical resection.

in association with coarctation of the aorta are encountered and suitable for excision followed by the use of aortic grafts to restore aortic continuity

Traumatic aneurysms of the aorta usually just below the origin of the subclavian artery may follow car accidents when the upper thorax is crushed and can be treated radically Aneurysm of the pulmonary artery apart from mycotic ones of its branches in infected ductus arteriosus is rare but produces diagnostic problems important to the thoracic surgeon (Fig 20 1) De Bakey (1955) reported his results after excision of 35 thoracic aneurysms 15 being saccular 14 fusiform and 6 of the dissecting type in addition 2 had aneurysms with coarctation of the aorta There were 7 deaths Bahnson (1955) has excised 20 thoracic aneurysms with the loss of 8 patients

Surgical treatment of thoracic aneurysms

Excision with or without replacement of the main channel by grafts is the surgical aim

Excision without grafts This method is naturally applicable only to aneurysms of individual arteries of which the innominate is the commonest or to removal of sa-

aneurysms of the main aorta, aneurysms of the innominate artery by pressure effects produce the establishment of a good collateral circulation Bahnson excised 5 such aneurysms without a detectable clinical deterioration of the cerebral circulation The same writer has demonstrated that many saccular aneurysms of syphilitic origin start as localized " blow-outs " so that they have a reasonable neck leading out to the sac, which may be enormous Such aneurysms can be excised after clamping-off this neck after the aorta above and below has been mobilized so that, if necessary, temporary clamps can be placed across them, such precautions and the preliminary dissection must be executed meticulously before the sac itself is attacked If an attempt is made to dissect out the sac before these essential preliminaries, the danger of entering it is obvious as these aneurysms often infiltrate tissue, such as the bone of the vertebral column, and so obliterate any safe line of dissection The neck is then secured by a multi-toothed clamp and the sac excised As much sac as possible is excised as, disconnected from its blood supply, it may provide a serious focus of infection The tissue in the clamp is then sutured meticulously Bahnson has resected saccular aneurysms of the ascending and descending aorta and from the arch itself by this method

Excision with grafting The work of Gross on the use of homografts in aortic coarctation paved the way for their use in treating thoracic aneurysms De Bakey and Bahnson both have played a large part in popularizing these methods Depending on the cause and site of the aneurysms the main pre-occupation of the surgeon will be anxiety as to the blood supply to the spinal cord during operation, if the aneurysm is associated with a coarctation of the aorta there is no anxiety on this score, because of the well-established collateral circulation

In the absence of a coarctation, the aorta may be clamped at the level of the subclavian artery for periods of fifteen to fifty minutes with varying degrees of risk to the blood supply to the cord Neurological hurt can never be anticipated accurately, in some patients occlusion for fifteen minutes may leave sequelae As de Bakey points out, prevention of spinal cord damage from ischaemia is the major problem in resecting aneurysms arising at levels up to the left carotid artery as clamping of the aorta for periods up to one hour does not seem to have caused damage to other tissues If the aneurysm does not reach higher than the sixth or seventh thoracic vertebra the surgical excision can be carried out without great anxiety as to the fate of the blood supply to the cord

The use of shunts The two methods which minimize the danger to the cord are the use of shunting procedures or hypothermia The shunts may be temporary grafts made of preserved grafts which could be heterogeneous (pig aorta has been used by Chamberlain, 1955) or of plastic material sutured to the descending aorta below the aneurysm or permanent In the second instance, a human aortic graft is sutured into place as for the temporary graft and an aneurysm involving the aortic arch of the saccular type could be excised so that sufficient blood supply was left for an adequate cerebral circulation and the graft left in permanently Ambitious attempts have been made to replace the aortic arch itself with grafts that have re-established continuity with the carotids and the left subclavian artery The temporary grafts are sutured to the aorta by the use of a Satinsky-type clamp which picks up part of the wall yet leaves a lumen big enough for satisfactory circulation while the graft is actually sutured in position

Hypothermia The use of shunts clearly entails a good deal of extra technical work and increases the hazards by requiring extra suture lines in tissue that is not basically healthy Hypothermia undoubtedly decreases the risk of spinal cord damage and enables the aorta to be clamped for periods up to or over an hour as the oxygen demands of the neural tissue will be decreased

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CONGENITAL HEART DISEASE

INTRODUCTION

These defects produce two different groups of patients, those with cyanosis (th cyanotic group) and those without cyanosis (the acyanotic group) If there is an openin between both sides of the heart cyanosis may develop in the second category if the shun becomes reversed In both groups there are examples of pulmonary plethora an pulmonary ischaemia In many of the patients there are anatomical defects that can b corrected, or in whom physiological handicaps can be overcome The availability c surgical treatment and the establishment of the exact nature of the deformities by clinica and radiological methods, often supplemented by cardiac catheterization and angiocardic graphy, means that congenital disease is no longer an academic problem of cardio-vascula pathology Maude Abbott (1928) and Brown (1939 and 1950) have provided admirabl accounts of the anatomical and pathological pictures Taussig (1947), by modern clinical radiological and physiological methods, showed that an accurate diagnosis of the extent site and nature of the congenital defects is possible in most instances and a correct estimat of the frequency of the lesions obtained Since then a vast literature on the subject ha developed

Incidence of congenital cardiac lesions

It is not possible to give an accurate account of the incidence of congenital heart diseas in the general population as each clinic often deals with patients coming from areas remot from the district. That the problem is a large one can be seen from McKeown (1953 who investigated cases of congenital heart disease born to Birmingham mothers in th years 1940–1949 In 194,418 total births, 633 examples of congenital heart disease wer identified 236 of these were proved at autopsy and 242 clinically , 145 were accepted fror the death certificate records and 10 from the report of the School Medical Officer Mos of the 236 patients coming to autopsy were infants, many with other malformations

To surgeons, an example of McKeown's breakdown of the cases seen at post-morten or examined by consultant physicians is of special interest as this shows conditions capabl of surgical correction if we include transposition of the great vessels, which, so far, ha

SEX RATIOS FOR SPECIFIC CARDIAC MALFORMATIONS (MACMAHON, MCKEOWN, RECORD)

Malformation	*Birmingham 1940–49*		Data recorded by Abbott (1936)	
	Number of cases	Percentage of males	Number of cases	Percentage of males
Transposition of great vessels	47	72	81	52
Persistent common truncus arteriosus	17	47	21	52
Pulmonary stenosis	42	69	150	50
Coarctation of aorta	32	44	87	71
Septal defects	121	55	122	46
Patent ductus arteriosus	62	39	105	34

been treated with limited success Maude Abbott's figures of great interest and well known, are not comparable because they report the analysis of selected post mortem material collected by the author for a specific purpose

Conversion of some acyanotic lesions into cyanosis

The causation of cyanosis in the true cyanotic group is central in origin being due to a right *to-left shunt across a septal* defect in the presence of hypertrophy of the right ventricle contracting against obstruction of the pulmonary arterial outflow due to infundibular or valvular stenosis or hypoplasia or atresia of the pulmonary artery In the Eisenmenger complex the heart has all the defects seen in the tetralogy of Fallot save the element of pulmonic stenosis when later in life pulmonary hypertension *develops as a result of changes* in the lung vasculature right ventricular hypertrophy follows to cause shunt reversal.

In some acyanotic lesions, blueness will develop when the left to-right shunt is reversed Reversal of the shunt through a septal defect or a ductus arteriosus due to increasing pulmonary hypertension associated with right ventricular hypertrophy may develop later and accounts for cyanosis ensuing in the teens or the twenties The cyanosis may be peripheral as a result of the decrease in cardiac output when the left ventricle begins to *fail as in a patient with a patent ductus arteriosus The later development of cyanosis* in patients with pure pulmonary stenosis is explicable on the grounds of the right-sided heart failure venous blood being forced through an atrial defect Brock and Campbell have pointed out the extreme dangers under which patients live and they have a high incidence of sudden death Because of this patients with pure pulmonic stenosis and a steadily increasing right ventricular hypertrophy should be submitted to pulmonary valvotomy The cyanotic group always have a worse prognosis than the acyanotic and attempts to be more specific will be made when the treatment of individual defects is considered

These defects may be severe enough to cause death at birth or soon after but even in the grossest deformities the physiological and anatomical adaptation may be so flexible that *life is possible in spite of apparently hopeless mechanical defects Almost without* exception as *life progresses* the burden on either the right or left heart becomes greater and these patients have the added risk of developing bacterial endocarditis The polycythaemia of the blue babies is an excellent example of a physiological adaptation while the general tendency for the children to be undersized is in itself a mechanism that eases the heart's burden

There is no great evidence of a familial incidence though examples have been met of more than one member of a single family being affected arrest of embryological development before the eighth week or the development of defects later (foetal endocarditis) the result of maternal infection may be due to ante-natal influences rather than to genetic reasons This is supported by the not infrequent coincidence of abnormalities such as mongolism cleft palate and arachnodactyly *though in our series at the Birmingham* Children's Hospital this has been unusual

Investigation of congenital heart disease

Helen Taussig indicated the high degree of clinical accuracy obtainable by clinical and radiological examinations alone and how this could be correlated with the pathological anatomy obtained as the result of years of post mortem study The exact nature of the defects and their physiological and pathological *effects can be accurately diagnosed if the*

investigations include cardiac catheterization and angiocardiography, and Wood (1950) believes that a 90 per cent accuracy is obtainable in the living patient

History and clinical examination There is clearly no need to stress the value of a complete history too much has been said about the presence or absence of "blueness" and too little about the functional capabilities of the patients Dyspnoea and the exertional incapacity of the patient are not always easy to assess when severe in blue babies and associated with a history of squatting, a tetralogy of Fallot is often present The onset of cyanosis and dyspnoea should be discovered from the history if possible many of those



Fig 14 1 —The characteristic squatting position seen in a boy with Fallot's tetralogy

in the Fallot group are not cyanosed in the early months of life while a really late development of blueness is seen in the isolated pulmonic stenosis with an atrial defect or in septal defects when the shunt is reversed which may not occur till the late twenties or thirties The children with tetralogy of Fallot usually squat when tired, but this is not absolutely pathognomonic Clubbing of the toes and fingers are important signs, indicating a lesion causing central cyanosis supported by the high degrees of polycythaemia often met with in many of the cyanotic patients A careful look at the chest and neck may be of great value, e g arterial pulsation in the neck in ductus arteriosus and in coarctation of the aorta, the bulging pidgeon chest of right ventricular hypertrophy and the pulsation of collateral vessels in coarctation of the aorta

The careful noting of thrills, murmurs and the character of the second sound in the pulmonary area provides invaluable information and this has been well stressed by Wood (1950), especially important is the accentuation of the second element of the usually split second heart sound in pulmonary hypertension whereas in the pulmonic stenosis of Fallot's tetralogy it is single, clear and loud as the only sound heard is the aortic one The electrocardiogram studies are specially valuable in indicating whether one or other ventricle is predominant

The slender description given here of clinical assessment in comparison with the fuller accounts given in the chapters on angiocardiography and cardiac catheterization is in no way an attempt to minimize the value of clinical methods but justice to this aspect of the subject is impossible in a surgical work

The important help provided by cardiac catheterization and angiocardiography requires a fuller description because of the more recent advent of this scientific and accurate help

The following Chapters on angiocardiography and cardiac catheterization are applicable of course to acquired forms of heart diseases as well as to congenital deformities.

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CHAPTER 14

ANGIOCARDIOGRAPHY

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Much has been written about angiocardiography since the papers of Castellanos (1937) and of Robb and Steinberg (1938) The value of the method in the radiographic demonstration of the cardio-vascular structures and circulatory route is now well established This value lies not only in diagnosis but also in the provision of anatomical information to aid the planning of surgical treatment

The essential features of the investigation are two-fold Firstly, an injection of contrast medium, rapid enough to provide a single " bolus " which outlines in turn each part of the heart and the great vessels, if the injection is slow, the contrast medium will be insufficiently concentrated to outline clearly the individual structures, while the sequence in which the chambers and vessels fill will not be distinguishable The second essential is a rapid series of radiographs, showing the progress of this opaque bolus The normal flow from vena cava to aorta is complete within ten seconds but in abnormal circulations the time may be very much less Thus many pictures must be obtained in a few seconds if the circulatory route is to be demonstrated

The injection may be made intravenously (*venous angiocardiography*) or via a cardiac catheter whose tip is situated at the appropriate point in the heart or great vessels (*selective angiocardiography*)

Rapid serial radiography

A variety of methods has been used

1 *Direct radiography* (*a*) With manual change of cassettes, (*b*) with mechanical change of cassettes, (*c*) using roll-film moving intermittently through a single pair of intensifying screens (e g Elema apparatus), (*d*) using cut film in a similar way (Schonander AOT film changer)

2 *Indirect radiography* Photography of the image on the fluorescent screen

Indirect methods have made great advances with the advent of the image amplifier Already slow-motion ciné-angiocardiography is a practical and valuable method (Astley, 1955) although at present it is limited in its field area and definition In the future it is likely to make further progress and may well replace direct methods

Direct radiography with manual change of cassettes uses the minimum of special apparatus Two technicians, one to feed cassettes into a tunnel under the patient and another to remove them, can expose any number of films at rates of up to one a second Such simple methods as these can give very adequate results, although an occasional picture may be blurred by exposure before the cassette is quite stationary, but the risk of over-exposure to X-rays to which the operators are subjected if many examinations are undertaken must be considered However, simple pieces of apparatus, easily made in the hospital workshop, can overcome these difficulties Devices incorporating a stop mechanism that ensures the cassettes are really stationary when exposed have obvious advantages A modified form of the conveniently compact manual-change apparatus

described by McGregor (1949) has been used by the author With it any number of pictures may be taken at a rate of two to three per second

Whatever the method desirable technical features are short exposure times (one-twentieth of a second or less) and a fine stationary grid to increase the contrast of the pictures Greater tube-film distances than 30–40 inches do not appear essential provided the tube focal spot is not large The possibility of obtaining two simultaneous sets of films in planes at right angles e g simultaneous anteroposterior and lateral views is worth consideration (Fredzill 1950)

The rate of radiography

The radiographic methods fall into three broad groups in their application to the angiocardiography of congenital heart disease In the first group are those methods that give one to two pictures per second These provide valuable diagnostic evidence and anatomical information that aids the planning of surgery (e g by indicating the presence and size of vessels suitable for anastomosis)

But for a greater degree of diagnostic value a more rapid series of films is indicated probably four to six per second are desirable and methods capable of this rate comprise the second group An instance of this need is given by a child with transposition of the great vessels examined by the writer All the contrast medium had passed through the heart within two seconds Thompson (1949) showed how an aortic coarctation might be demonstrated only by chance with fewer exposures than two per second

The third group comprises those methods that give more than six pictures per second A very rapid direct method was first introduced by Lind and colleagues (1949) the Elema roll film apparatus will operate at 12 pictures per second in two planes while 32 to 64 pictures per second are obtainable by indirect ciné methods using image amplification Simultaneous marking of the exposures on an electrocardiogram relates the electrical and functional activity of the heart In addition to research purposes there are special diagnostic problems particularly those concerned with very small children in which these ultra rapid methods find application

The injection

The contrast medium is a 70 per cent solution of sodium acetrizoate For *venous angiocardiography* usually using a vein at the elbow or groin the dose for small children is calculated from the formula of 1 5 ml per kilogram of body weight with a slight reduction for larger subjects Thus a baby may receive 5–15 ml while an adult needs 40–70 ml

The necessity for rapid injection has been emphasized A relatively slow flow of medium gives poor concentration in the heart and indifferent pictures the chambers and great vessels may not be easily distinguishable one from the other since several will be filled at once The time for the completion of injection should be one second over two seconds should be considered too slow With a large volume to inject this is no mean feat The plunger of the syringe should move freely Its nozzle can be specially bored to have the widest possible channel The cannula tied into the vein should have the absolute maximum size of lumen that is possible The solution and the syringe should be warmed to body temperature before use If they are too cold the medium will crystallize out if too hot the plunger may not move freely in the syringe A convenient procedure is to tie the cannula into the vein while the patient is still in bed A stilette is inserted during transportation to the X ray theatre and until everything is ready Then the syringe is

connected to the cannula (either directly or via a short, strong flexible connection) and the injection made

For *selective angiocardiography* (Chavez, 1947, Jonsson, 1949), the widest possible cardiac catheter should be used and additional holes bored near its tip are useful Under fluoroscopic control the catheter tip is negotiated into the appropriate chamber, thus to demonstrate an infundibular stenosis it may lie in the outflow tract of the right ventricle and in the pulmonary trunk when the left side of the heart is under examination The dosage of contrast medium is 1 2 ml per kilogram of body weight, injected by a mechanical or pneumatic pressure syringe (to overcome the resistance of the catheter and to obtain an injection time of one to two seconds)

A preliminary radiograph, to ensure correct exposure, is advisable Generally speaking, rather dark films are required to show the contrast medium within the heart

Anaesthesia

For adults simple sedation is sufficient and the examination may be conducted in the erect position

For children (except small babies) anaesthesia is generally required and the recumbent posture used Skilled anaesthesia with adequate oxygenation is essential The patient is often a bad risk, his circulation is to be insulted by the rapid injection of a considerable volume of hypertonic fluid, he may have a poor pulmonary circulation that for a time will be blocked almost completely by the bolus of contrast medium

Our own procedure is to sedate a child beforehand with rectal thiopentone Further thiopentone is injected intravenously only if absolutely necessary to maintain the selected position of the subject Then an ultra-short acting muscle relaxant is given intravenously (Inglis and Astley, 1953), while oxygen is administered by mask As soon as respiration and the muscular twitchings of depolarization cease, the injection of contrast medium is made and the rapid series of radiographs taken The anaesthetist then maintains ventilation until spontaneous respiration returns, thirty to sixty seconds later

Dangers of the examination There is a small but definite risk, greatest by far in cyanotic heart disease where the slightest upset may tilt the precarious balance between life and death If angiocardiography is reserved for such serious conditions, the mortality rate has been estimated at about 2 per cent In the investigation of other diseases there is much less risk and the death rate is under 0 3 per cent Dotter and Jackson (1950), who gave these figures, collected information about 23 angiocardiographic deaths, of which 21 were in the study of congenital heart disease (17 with cyanosis) Eight occurred within ten minutes of the injection, 9 between fifteen minutes and three hours and the remaining 6 between six hours and three days At autopsy, sometimes pulmonary congestion and oedema or collapse were found but rarely was the cause of death revealed

The dangers to be considered are those of

1 Anaesthesia,
2 Idiosyncrasy and toxic effects,
3 Obstruction of an impaired pulmonary circulation by the bolus of contrast medium

As used for urography, idiosyncrasy to contrast media is very rare, Pendergrass (1942) found a death rate of only 0 0039 per cent in two-thirds of a million examinations In the angiocardiographic deaths described by Dotter and Jackson, sensitivity tests were performed in most instances and all were negative, which is evidence against the participation of an antigen-antibody reaction Gordon (1950) found no instances of acquired idiosyncrasy at delayed repeat examinations

Toxic effects are likely if there is over-dosage or failure of elimination Therefore the procedure is contra indicated if renal function is poor It is also contra indicated by severe hepatic disease since some of the medium is eliminated by the liver, especially when there is associated kidney damage

In some of the recorded fatalities convulsions have been noted This has been especially so when repeated injections of contrast medium have been given at a single session and when the aorta was partially or completely transposed i.e under conditions where the cerebral circulation received a very high concentration of diodone Broman and Olsson (1949) showed that altered cerebral vascular permeability is the probable cause It is therefore our practice always to confine the examination to a single injection when a repeat is necessary this is postponed to a later date To wait for only half an hour or so between injections is unsound as high concentrations of the contrast medium are still circulating indeed it is possible to observe opacity in the renal pelvis in a radiograph taken as late as twelve hours after a single dose

The commonest form of death is respiratory arrest immediately or shortly after the injection So far this has not been satisfactorily explained possibly several factors are concerned acting in a vicious circle

1 The pulmonary blood flow often already impaired is blocked for several seconds by the bolus of contrast medium

2 The blood pressure falls as a result of the vasodilation produced by the direct action of the medium on the vessels This property is partly inherent in the drug and partly non specific being related to the rate of injection and the elevated osmotic pressure (Gordon 1950)

3 As a result there is stasis of contrast medium in the lungs hindering oxygenation and altering the permeability of the blood vessels to cause pulmonary oedema

4 The cerebral circulation often receives a high concentration of medium for a relatively long period vascular permeability is increased and direct action on the medullary centres depresses respiration

5 The effects of the contrast medium may be prolonged if the depressed blood pressure brings into play a temporary renal arterio-venous short-circuit *

These factors which summate to produce respiratory failure must vary in their importance in different individuals In combating them it should be remembered that

1 Adrenalin as a restorative is contra indicated because it may cause pulmonary oedema (Elkeles 1948)

2 Such drugs as nikethamide are the stimulants of choice since they act directly on the respiratory centre

3 Artificial respiration as well as aiding the failing oxygenation of blood will ameliorate pulmonary oedema

Another risk of angiocardiography that must be considered is that of over-exposure to X rays Over irradiation of the patient is unlikely in a single examination but as well as angiocardiography other radiological procedures (ordinary radiography fluoroscopy and cardiac catheterization) are likely to be undertaken and the total dosage of radiation administered in all these may be considerable (*Hills 1950*) The assistance of a physicist in checking the dosage is advisable Over irradiation of the medical team

* The writer has personal knowledge of three angiocardiographic deaths One occurred in a three year-old girl with Fallot s tetralogy twelve hours after a single injection. The post mortem blood level of diodone was less than the calculated expected value But probably a renal arterio-venous shunt would only have to be effective for a short time for the vascular effects of the diodone to be aggravated

conducting angiocardiography is a perhaps greater risk that must be avoided Necessary precautions are

1 The use of a localizing cone that strictly limits the X-ray beam to the picture area

2 The use of a radio-opaque screen between the patient and the doctor making the injection or the use of remote-control pressure injection apparatus

3. The wearing of protective aprons and gloves by all near the apparatus, the anaesthetist in particular needs to wear gloves as his hands may be near the picture area

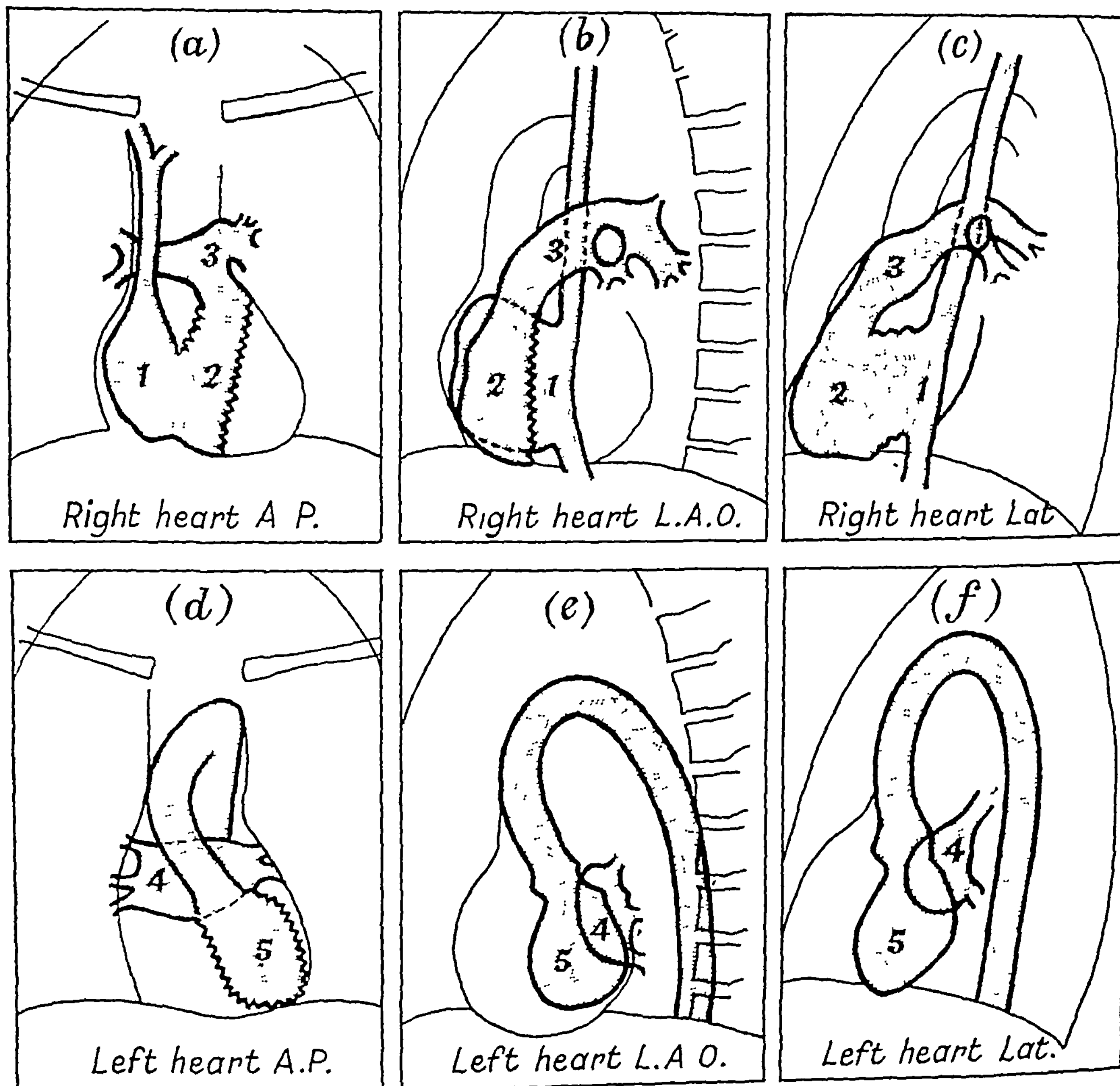


FIG 14 2—Normal angiocardiographic appearances (after Dotter and Steinberg)
1 = right atrium, 2 = right ventricle, 3 = pulmonary artery, 4 = left atrium, 5 = left ventricle These numbers are also used in subsequent illustrations

Normal appearances. The normal appearances of the heart and great vessels have been described by Dotter and Steinberg (1949), with idealized diagrams made after a study of over six hundred examinations

In children the writer has found that the right heart is shown between 0 5 and 3 5 seconds from the start of the injection, the left heart and aorta are shown between 4 5 and 8 5

seconds But these times are variable and they tend to be a little longer in adults The speed of injection is also important as a trickle of contrast medium after the main bolus may prolong visualization

In the frontal projection *the right heart is U-shaped* The descending limb on the right is produced by the atrium The transverse limb is often indented on its lower border at the site of the tricuspid valve (just to the left of the mid line) to the left of this point is the inflow tract of the ventricle and the ascending limb of the U is its outflow tract This merges into the main pulmonary artery which divides so that its right branch covers the top of the U and its left branch turns sharply downwards The main artery and its left branch rather than the pulmonary conus comprise the middle segment of the left heart border (Miller 1950)

When the right atrium fills from the superior vena cava it is not unusual for some contrast medium to pass in a retrograde manner into the inferior vena cava and hepatic veins during atrial diastole (Such reflux occurring during atrial systole is pathological according to Hedman 1953) *The right ventricle does not usually fill as solidly as the* atrium The left atrium lies in such a position that it is behind the gap in the U of the right heart The shadow of the left ventricle follows the general line of the left heart border crossing the left atrium to the aorta

In the left anterior (or right posterior) oblique projection the four chambers are maximally separated and the interventricular septum is seen end-on The aorta is well shown

The lateral projection gives a profile delineation of the right ventricular outflow tract that is of value in the direct demonstration of a stenosis (although its constancy in several pictures is essential as the normal variations during the cardiac cycle may momentarily simulate a narrowing)

Congenital heart disease It is in the study of this subject that angiocardiography finds its main application The method is not a substitute for such investigations as physiological studies and cardiac catheterization But it is complementary to these playing a significant part in the process of diagnosis and in the planning of surgical treatment Perhaps its greatest value lies in the anatomical information which it alone can give

Tetralogy of Fallot and allied conditions *The angiocardiographic signs of the* tetralogy of Fallot are

1 Simultaneous flow of contrast medium from the right heart into the aorta and into the *main pulmonary arteries this is seen in the first three seconds*

2 Delayed and decreased filling of the peripheral vessels in the lungs These secondary and tertiary branches are usually small the primary branches on the other hand fill early and may sometimes be normal in size or show post-stenotic dilatation

3 The direct demonstration of the infundibular or pulmonary stenosis

4 Contrast medium may enter the left ventricle from the right through the ventricular septal defect and pass back to the right when the left heart is filled

Often the diagnosis by simpler methods is not in doubt and the angiocardiographic evidence is only confirmatory Nevertheless the atypical case where every available item of evidence is necessary *does* occur and here angiocardiography is of diagnostic value

However its greatest value lies not as a purely diagnostic measure but as a routine pre-operative *investigation to yield anatomical information* viz.

1 Whether or not both main pulmonary arteries are present their sizes and positions

2 The position of the aortic arch

3 The size and position of its main branches

4 The type of the pulmonary stenosis

The degree of over-riding of the aorta can be judged in the frontal projection by the amount of contrast medium that passes into it In the left oblique projection the position of the aorta relative to the ventricular septum can be judged directly A flow through the septal defect is not usually a prominent feature in angiocardiography at one to three films per second unless the defect is an unusually large one (perhaps such that functionally there is virtually a single ventricle) With ciné radiography a trans-septal shunt is more often seen and it may occur in both directions—into the left ventricle when the right heart is filled and later in the reverse direction if enough contrast medium passes through the lungs to give good filling of the left heart



FIG 14 3



FIG 14 4

FIG 14 3—Tetralogy of Fallot (age 4 years)

At 1 second after injection there is simultaneous filling of the main pulmonary arteries and of the aorta, which is arching to the right Subsequent films show reduced and delayed filling of the peripheral pulmonary vessels The left pulmonary and left subclavian arteries appear very suitable for a Blalock s anastomosis (Ao = aorta)

FIG 14 4—Infundibular stenosis (age 13 years)

A short stenosis (barbed arrow) is demonstrated by selective angiocardiography with the catheter tip in the outflow tract of the right ventricle Note the cusps of the pulmonary valve (plain arrows)

Direct demonstration of the pulmonary stenosis when it is of the common infundibular type is possible in both frontal, oblique and lateral positions There may be a linear narrowing of the ventricular outflow tract or there may be a shorter, more localized narrowing with a wider segment beyond it A valvular stenosis is less common and is best sought in the left oblique or lateral projection, there is often some degree of associated infundibular narrowing Venous angiocardiography may fail to give clear demonstration of the type of stenosis because of overlying shadows, thus, in the left oblique position it may be obscured by contrast medium in the superior vena cava Selective angiocardiography is an advantage here as the injection can be made immediately below the stenosis, if only the stenosis is

to be demonstrated the dose of contrast medium injected through the catheter may be reduced by a third.

If examination is to be limited to a single plane the frontal position is preferred as it gives the maximum of anatomical information the pulmonary and subclavian arteries of the two sides can be compared and their suitability for operation assessed But if the presence of a pulmonary stenosis is uncertain or if it does not appear to be infundibular in type as judged in this view a repeat examination in the lateral or left oblique position is indicated

Tricuspid stenosis or atresia In this condition the flow of contrast medium is from the right atrium through a septal defect to the left atrium thence to the left ventricle

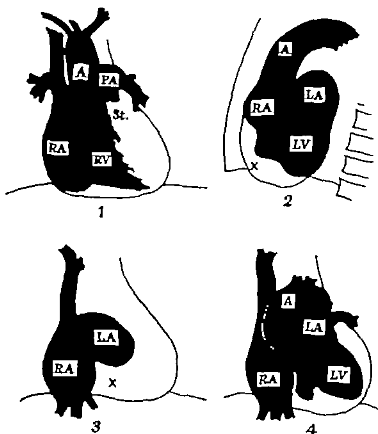


Fig 14 3

(1) Angiocardiographic appearances in Fallot s tetralogy (see Fig 14 2)

( ) The lateral angiocardiogram in tricuspid atresia.
(X = site of non-filling of the rudimentary right ventricle.)

(3) and (4) The frontal angiocardiogram in tricusp d atresia.
(X = site of non-filling of the rudimentary right entricle in the early film later a rudimentary chamber may be seen t this site)

and aorta Sometimes a rudimentary right ventricle fills from the left through a second septal defect The pulmonary arteries fill later than the aorta but they are usually small and little medium enters the lungs the main pulmonary supply may be by a patent ductus or enlarged bronchial arteries

In the frontal projection the space normally occupied by contrast medium in the inflow tract of the right ventricle to the left of the tricuspid notch is conspicuously empty in the early films but there is considerable opacity in the upper part of the heart shadow where both atria are filled at the same time In later films a rudimentary right ventricle

may be seen to fill In the lateral view, the non-filling of the right ventricle in the early pictures is well seen anteriorly, just above the diaphragm

The usual finding is that the flow of contrast medium into the lungs is poor, information of the presence, size and position of the pulmonary arteries is therefore useful pre-operative data

When there is associated transposition of the great vessels there may be a good pulmonary flow (Astley, Oldham and Parsons, 1953), so that no benefit will result from a Blalock anastomosis. Precise demonstration of the route of the pulmonary circulation is aided by the selective method of examination, with the catheter tip in the left ventricle

Isolated pulmonary stenosis. This is often valvular, but sometimes infundibular. The main circulatory route is normal but the stenosis may be demonstrated directly while its presence is shown indirectly by delayed filling of the smaller pulmonary vessels and slow emptying of the heart There may be post-stenotic dilatation There should be careful search, preferably in the left oblique position, for a right-to-left shunt through the foramen ovale or an associated septal defect Selective angiocardiography, with the catheter tip in the ventricular outflow tract, aids direct demonstration of the type of stenosis

Complete transposition of the great vessels. Two types occur (Astley and Parsons, 1952), this agrees with the descriptions of other writers (Campbell, 1950), although Castellanos (1950) elaborates the classification to four types

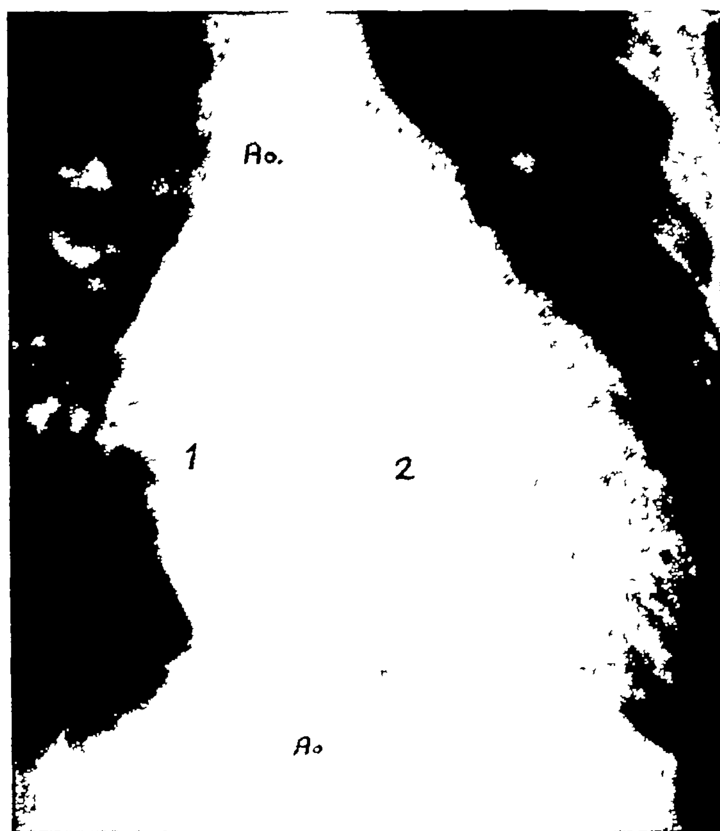


FIG 14 6



FIG 14 7

FIG 14 6—Complete transposition of the great vessels (age 3 years) 2 seconds From the right heart the medium enters the aorta, which is arising near the midline (Type 1) The main pulmonary artery is not identifiable and little medium enters the lungs despite their congestion

FIG 14 7—Complete transposition of the great vessels (age 9 months) 0 5 second As above, but the aorta originates over the right ventricular outflow tract (Type 2)



(a)



(b)

Fig. 14·8 — Ventricular septal defect (age 0 months) (a) 1·4 seconds (b) 3·0 seconds.
The circulatory route is normal, without trans-septal flow. The pulmonary artery is larger than the aorta and there is pulmonary congestion.



Fig. 14·9 — Atrial septal defect (age 5 years) ·5 seconds.
The circulatory route is normal, without trans-septal flow. The pulmonary artery is very large

In Type I the aorta appears in the frontal view to originate like the over-riding aorta of Fallot's tetralogy. Type II is quite characteristic, the aorta arises well to the left, over the outflow tract of the right ventricle It ascends towards the right at a variable inclination, in so doing often constituting the left middle segment of the cardiac outline It arches over the left bronchus and descends just to the left of the midline, occasionally it arches over the right bronchus and descends more to the right In both types the medium passes from the right heart in high concentration into the aorta and its branches The heart empties quickly, with little or no filling of the left chambers and lungs, the main pulmonary trunk is not demonstrable in the frontal view Since many, but not all, of the children with complete transposition have grossly congested lungs, this lack of filling of such big vessels is a conspicuous feature

In the lateral or left oblique position the aorta is seen to arise more anteriorly than normally. In these positions a trans-septal shunt may be shown by high speed or ciné methods if the two circulations are intermixing through a septal defect, slower radiographic rates often fail to show the site of this intermixing

Uncomplicated septal defects. In general, left-to-right shunts through uncomplicated atrial or ventricular septal defects are best demonstrated by cardiac catheterization

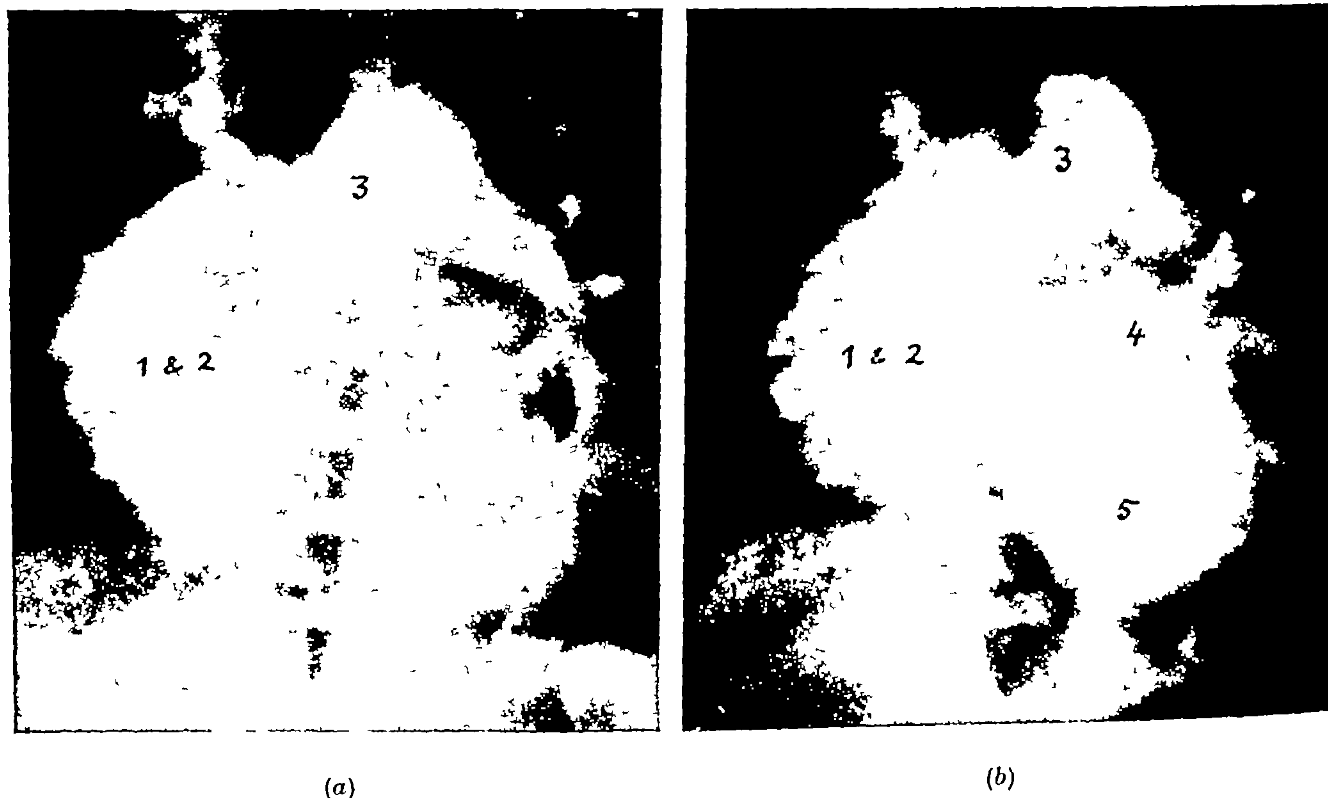


Fig 14 10 —Interatrial septal defect (age 1 year), left oblique view (*a*) 1 second, (*b*) 1 5 seconds Trans septal flow from right to left has occurred between 1 and 1 5 seconds, giving direct evidence of the lesion

Injection of contrast medium into the right heart is unlikely to demonstrate trans-septal flow against the pressure gradient in the early part of the examination (Figs 14 8 and 9), later, when the contrast medium has passed through the lungs into the left heart, densities are poorer and the detection of refilling of the right heart is uncertain (although it is possible by ciné radiography)

Angiocardiography has greater chance of success in the demonstration of uncomplicated septal defects if the subjects are infants or small children, provided high speed methods

(Lind and others 1953 1954) or ciné radiography (Astley and Oldham 1956) are used (Fig 14 10) Under these circumstances even though systolic pressures are higher in the left heart than in the right a right to-left trans-septal flow mav be detectable after a venous injection.

Selective angiocardiography with the catheter tip through the deficiency into the left atrium is a useful method of determining the size and position of an atrial septal defect (Björk and others 1954)

Patent ductus arteriosus An uncomplicated patent ductus producing a left-to right shunt is usually best detected by cardiac catheterization as the angiocardiographic signs are not very reliable High-speed or ciné methods give most chance of success Early in the examination there may be loss of concentration of contrast medium in the pulmonary artery during diastole as a result of dilution by non-opacified blood from the aorta (Lind 1954) Later when the left heart fills the pulmonary artery may show persistent opacity or may refill from the ductus after normal emptying however these density changes are apt to be uncertain of interpretation There is often a bulge in the aorta at the sight of insertion of the ductus but it is not constantly present nor is it absolutely indicative of patency

Should certain angiocardiographic demonstration of a ductus arteriosus be desired the use of retrograde aortography which is highly successful is indicated this will be described later (p 352)

Venous anomalies It is not uncommon to find variations in the anatomy of the

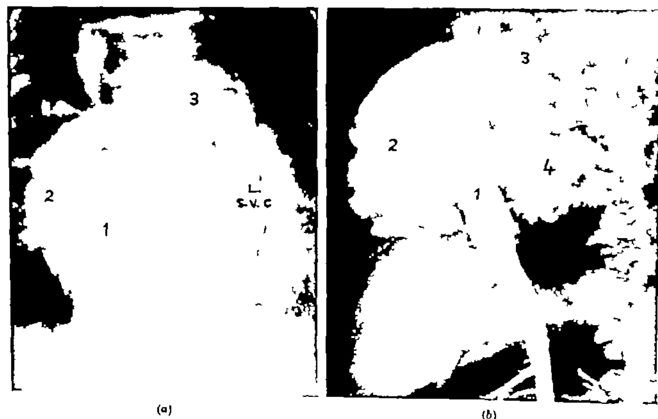


Fig 14 11 —Bilateral superior vena cava abnormal cardiac rotation.

( ) 3 seconds. The right trium lies medial to the right ventricle, which occupies the right cardiac border The left vena ca a (L.S.V C.) enters the coronary sinus nd the right ena cava enters normally The hook-like structure medial to the left vena cava is due to retrograde filling of an azygos vein. Later films showed the left trium t occupy the gap between the right trium and the left vena cava. (Injection at left elbow)

(b) seconds (left oblique view) The right trium lies behind the right entricle and the tricuspid alv i bnormally high in position. The figure 4 indicates the site of the left atrium s shown by later films. (Injection from the groin.)

great veins, information concerning which may assist the surgeon The superior vena cava, for instance, may lie on the left or it may be bilateral

One or more of the pulmonary veins may drain into the right atrium (usually via the superior or inferior vena cava or the coronary sinus)

Coarctation of the aorta. The aorta is demonstrated between five and nine seconds from the start of a venous injection Better densities are obtained by selective angiocardiography with a rapid injection through a catheter whose top lies in the pulmonary trunk The left anterior oblique view shows a left aortic arch maximally unfolded but the site of coarctation is often projected over the spine in this view Therefore the lateral position is preferable The information provided may

1 Confirm the diagnosis (important in the early years of life)
2 Indicate the calibre of the aorta above and below the coarctation
3 Show the character, degree, length and situation of the narrowing
4 Show the position of aortic branches relative to the narrowing
5 Show the post-operative condition, post-operative aneurysms have been demonstrated (Salen, 1948)

The radiographic appearances are closely related to the operative findings, they may indicate whether surgery is possible and help in its planning Thus a long, slowly narrowing stenosis is more difficult at operation and with other unfavourable circumstances may mitigate against surgery Multiple (inoperable) stenoses are occasionally present and prior knowledge of the condition will save fruitless thoracotomy, or indicate the use of a graft. If a good injection fails to produce adequate density in the aorta (e g where there are other associated cardiac defects or where there is a very large heart), aortography will give better pictures

Acquired cardiovascular disease ; mediastinal tumours. Most types of acquired heart disease have been studied but practical application is limited In rheumatic disease the identification of thrombi within the chambers might aid treatment A pericardial effusion can be demonstrated easily (Dotter, 1949, Williams, 1949) by observing an increase in the space between the right atrium and the right lung (normally not exceeding 2–4 mm) In constrictive pericarditis very slow circulation through the heart may be found Masses adjacent to the heart can be differentiated from pericarditis

The method is of value in the early diagnosis of syphilitic aortitis (Dotter, 1949) The signs are increased diameter of the aorta (over 38 mm in its mid-ascending portion), an irregular lumen (the variations are less gradual than with non-syphilitic causes, dilatation and irregularities may be shown in relatively inaccessible sites such as the sinus of Valsalva), tortuosity of the aorta (produced also by arteriosclerosis but a sign of value in the younger subject where degenerative disease is unlikely), variations in the thickness of the aortic wall (normally 2 mm), the presence of an aneurysm

An aneurysm ordinarily becomes opaque at the same time as its vessel of origin, so that its nature becomes apparent On rare occasions, clot or a narrow neck may impede filling

Distinctive changes have been observed in dissecting aneurysm (Golden, 1949). The aortic lumen is more or less abruptly narrowed and the aortic walls are thickened at the site of the dissection Contrast medium may penetrate within the false passages

By ordinary methods the differentiation of an aneurysm from a mediastinal tumour may be difficult For instance, a tumour close to a pulsating structure may itself appear to pulsate but an aneurysm may *not* pulsate In such cases angiocardiography can give otherwise unobtainable information (Sussman, 1947, Dotter, 1949) A mediastinal tumour

does not usually impair the integrity of the great vessels except by compression or displacement unless there is malignant infiltration which produces irregular constriction or occlusion (in the X ray appearance akin to that of malignant disease of the gut)

In addition to diagnostic value delineation of the structures bounding a mass (preferably in two views to give maximum three-dimensional information) aids the planning of operative attack Obstructive lesions at the thoracic inlet are particularly easy to demonstrate

Pulmonary disease Many pulmonary diseases have been investigated by angiocardiography A condition in which the method is particularly helpful and one which is

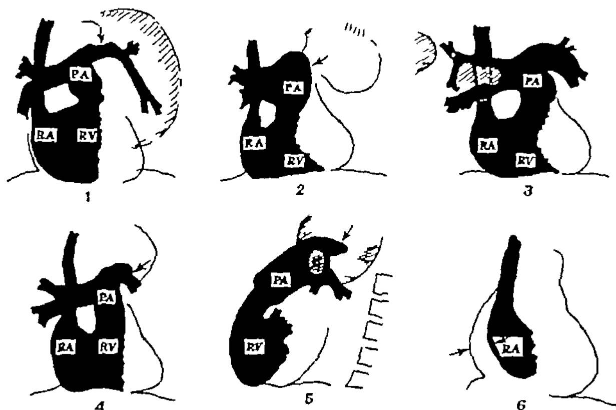


Fig 14 1 —Angiocardiographic evidence of inoperability of bronchial carcinoma (after Dotter Steinberg and Holman, 1950)

The arrows indicate neoplastic involvement of the pulmonary arteries. Top right shows a mediastinal secondary deposit from peripheral primary carcinoma bottom right shows pericardial invasion (note the wide space between the arrows).

eminently amenable to surgery is a pulmonary arterio-venous fistula At 1½–2 seconds after injection a large vessel is seen entering the often small pulmonary mass and a little later at 2–4 seconds a similar vessel is seen leaving it Sometimes more extensive vascular communications may be shown

Angiocardiography may help the diagnosis and prognosis of bronchial carcinoma (Neuhof 1949 Steinberg 1950) Infiltrating malignant lesions surround or engulf the neighbouring vessels producing irregular alterations in the outlines of the larger arteries and occlusion of the smaller ones Circumscribed tumours however only displace the adjacent vessels Exceptions occur—a malignant tumour is occasionally so circumscribed that it displaces rather than engulfs and a chronic inflammatory process may sometimes obliterate vessels

Perhaps the greatest value of the investigation in bronchial carcinoma is to assess prognosis Dotter *et al* (1950) have given the following criteria of inoperability

1 Partial or complete occlusion by tumour of the left pulmonary artery within 1½ cm of its origin, or of the right pulmonary artery proximal to its bifurcation

2 Partial or complete occlusion of the great mediastinal veins due to tumour in the mediastinum

3 Displacement and deformity of vascular structures by mediastinal metastasis in the presence of a known peripheral cancer

4 Demonstration of pericardial invasion

They prefer the frontal view for the right pulmonary artery and the left oblique for the left pulmonary artery (i e the vessels are observed sideways-on)

Absence of angiocardiographic evidence of inoperability does not mean the lesion is operable, on the other hand, evidence of inoperability must be convincing to be significant

They maintain that no patient should be denied exploratory surgery on the basis of the angiocardiographic appearances alone But they find the additional evidence yielded enables the planning of the most suitable approach, *it informs the surgeon of otherwise* hidden structures behind the tumour and reduces the duration of protracted explorations





Fig 14 13 Fig 14 14

Fig 14 13 —Coarctation demonstrated by counter-current aortography

Adult type' of coarctation in a girl aged 11 months Injection of 4 ml of 35 per cent sodium acetrizoate into the bronchial artery

Fig 14 14 —Coarctation demonstrated by a catheter injection into the aorta

Male, aged 6 years Combined "infantile" and "adult' types of coarctation The aortic arch is hypoplastic distal to the common carotid and there is a more severe narrowing below the origin of the very large left subclavian artery (Injection of 10 ml of 50 per cent diodone through a catheter passed along the brachial artery)

Retrograde aortography

As already stated, the diagnosis by angiocardiography of a patent ductus arteriosus is not reliable Also, in certain circumstances the demonstration of an aortic coarctation

may not be entirely satisfactory To overcome these difficulties very successful use has been made of retrograde aortography (Radner 1948 Broden and others 1948–50) This examination however provides greater hazards than angiocardiography

Contrast medium is injected into the aorta by one of two methods viz

1 Via an artery such as the carotid axillary or brachial reaching the aorta against the normal flow of blood

2 Directly into the aorta by a cardiac catheter that has been inserted along one of these arteries

The first method against the normal flow of blood can fill the aorta adequately in infants Under one year it is possible to demonstrate a coarctation or patent ductus in this way (Fig 14 13)

Injection via a catheter inserted along an artery into the aorta is necessary for older subjects For demonstration of a coarctation the catheter need only reach the aorta at the origin of the innominate artery but when a patent ductus is suspect the catheter tip should lie well down into the ascending aorta If there is a patent ductus contrast medium passes into the pulmonary arteries such an alternative diagnosis as that of aneurysm of the sinus of Valsalva that has ruptured into the right ventricle or congenital aortic septal defect may be made if the catheter tip is in this position

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CHAPTER 15

CARDIAC CATHETERIZATION

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The human heart was first catheterized by Forssman in 1929 who courageously introduced a radio-opaque catheter into a superficial vein of his own arm and advanced it into the right auricle The technique was devised for the intracardiac administration of stimulants and was later employed to visualize the heart and pulmonary vessels by injection of contrast material

In 1870 Fick showed that the cardiac output expressed in litres per minute could be estimated by dividing the oxygen consumption of the organism expressed in c c per minute by the difference in oxygen content of a litre of arterial and mixed venous blood. This has come to be known as the direct Fick principle The oxygen consumption of the subject and the oxygen content of the arterial blood are readily estimated but a truly mixed sample of venous blood can only be obtained from the right heart chambers or pulmonary artery It was this latter obstacle which prevented application of the direct Fick principle in human physiological studies until 1941 when Cournand and Ranges employed Forssman s technique of cardiac catheterization to obtain mixed venous blood from the right atrium

This new method was cautiously applied but it soon became apparent that initial fears of massive venous or intracardiac thrombosis were unfounded and intensive study of the human cardiac output in health and disease was then undertaken by many workers It was found that errors in determination of the cardiac output may arise from incomplete mixing of the venous blood in the right atrium as a result of stream lining within the great veins and the influx of very unsaturated blood from the coronary sinus into this chamber To overcome this difficulty mixed venous blood was obtained from the cavity of the right ventricle by passing the catheter tip through the tricuspid valve but here efflux from the Thesbian veins occasionally caused considerable error Dexter and his associates finally demonstrated that consistent values for the oxygen content of consecutive samples of mixed venous blood could be obtained only if the catheter tip lay within the pulmonary artery because here alone was mixing invariably complete

The ability to manœuvre the cardiac catheter through the chambers of the right heart into the pulmonary artery with relative ease and impunity greatly widened the scope of this new method of investigation The information which may now be obtained by use of this procedure will be briefly summarized

The radio-opaque catheter—manipulated as a probe under visual control—will define the course of the great vessels entering and leaving the right heart chambers and may be used to delineate the size and position of the right atrium and ventricle Congenital defects of the atrial or ventricular septa may be demonstrated by its free passage into the left atrium or aorta

The mean pressures and pressure waves within the right heart chambers and pulmonary arterial tree can be measured and recorded by attaching a saline or electrical manometer to the cardiac catheter Valuable information on the haemodynamics of the pulmonary circulation has been obtained in this way and pulmonary arterial hypertension may now

be recognized before clinical radiological or electrocardiographic findings make its presc manifest Comparison of right ventricular and pulmonary arterial pressures is of gı value in confirming the presence of congenital pulmonary stenosis and localizing its posit

Truly mixed venous blood samples can be obtained simply and safely through cardiac catheter, and the cardiac output may be determined at rest and during exer by application of the direct Fick principle. Comparison of the oxygen content of bl samples taken simultaneously from the right heart and a systemic artery in congen cyanotic disease makes it possible to estimate the relative and absolute size of the syste blood flow and the flow of mixed venous blood to the lungs—information which is invalua in the pre-operative assessment of these patients

A special electrode-catheter may be employed to take intracardiac electrocardiogra The electrode is placed just proximal to the catheter tip and the form of the cardiogı has proved a useful additional method of locating the position of the tip This metl has been employed to aid differentiation between pulmonary valvular and infundibı stenosis

The rapid strides taken by thoracic surgery in recent years have made accurate diagn and assessment of congenital and acquired cardio-pulmonary disease an essential prelimin to surgical treatment Cardiac catheterization—primarily a research technique—now ho an established place in this field of clinical activity

Technique

Materials

Cournand's cardiac catheters are extremely radio-opaque and easily manipulated body temperature Size 6F to 8L, 125 cm in length, are convenient for general purpo whilst Size 5F is used in young children and infants where the superficial veins are poo developed Wide lumen, thin walled catheters are now available for intracardiac a retrograde aortic angiograms Electrode catheters, double-lumen catheters and cathet with inflatable balloons mounted proximal or distal to the sampling hole are also obtainal Autoclaving is the safest method of sterilization although it tends to reduce the life of catheter and formalin vapour or CTAB are alternative methods To increase manœu ability, the terminal 2 0 cm is moulded to an angle of 45 degrees by a blunt stylet wh is removed before use The catheters must be free from all traces of old blood bef autoclaving otherwise pyrogenic reactions may occur

A slow infusion of heparinized saline is maintained through the catheter to keep t lumen free from blood It is possible to take blood samples and pressure measureme without detaching the catheter from the infusion apparatus by use of a four-way t manifold, this will connect the catheter in turn to the infusion apparatus, saline manomet electrical manometer and blood sampling syringe, and also enables the saline manome to be primed from the drip bottle and automatically zeroes the electrical manometer wh it is not in use

The saline manometer is a glass tube, 100 cm. in length and 2 0 to 3 0 mm internal diameter, mounted vertically on a centimetre scale and connected to the four-way tap by a length of rubber tubing. It is filled and primed with heparinized saline from the drip bottle This will give mean pressures only and in order to measure systolic and diastolic levels and record the form of the pulse waves an electrical or optical manometer of sufficient rigidity to respond faithfully to frequencies of 5 cycles per second must be employed in

addition Several electrical manometers of the capacitance or inductive type are now available for this purpose and the pressure variations are thus converted into an electric current which may be observed and permanently recorded on a direct writing oscillograph Alternatively the pressure pulses may be monitored on a cathode ray oscilloscope and recorded with a mirror galvanometer on photographic paper Whichever method is employed, it is essential to have a dual or multi-channel recording device capable of taking a simultaneous electrocardiogram this permits continuous monitoring of the electrocardiogram during the investigation and provides the necessary time marker for the subsequent analysis of the records

Intracardiac pressure measurement is made by reference to atmospheric pressure and the horizontal plane of reference or zero level for the manometer should, ideally pass through the catheter tip Since the position of this is variable a fixed manometric zero is employed and this zero is usually defined as the horizontal plane passing through a point 5 0 cm below the manubrium sterni Manometric zero may be fixed permanently at 10 0 cm above the top of the screening table and any small correction between this level and the normal plane of reference can be made by measuring the antero posterior diameter of the thorax whilst supine

Arterial samples may be obtained through a medium bevel 20-gauge needle If repeated samples are required an indwelling Riley arterial needle is threaded into one of the brachial arteries

Accessory equipment which will be required includes cutting-down instruments for exposure of the vein all-glass syringes of 10 ml capacity for blood samples and sterile towels gowns masks and gloves

Estimation of the cardiac output by the Fick principle requires an accurate measurement of the patient's oxygen consumption whilst in a steady state A three to five-minute collection of expired air is taken into a fifty litre Douglas bag and this volume measured in a water gas meter alternatively a Tissot spirometer may be used for both collection and measurement Samples of the expired air taken in evacuated glass sampling tubes are analysed for carbon dioxide and oxygen contents in a Haldane Sleigh or micro-Scholander gas analysis apparatus A simpler but less reliable method employs a Benedict spirometer containing oxygen and fitted with carbon dioxide scrubbers

Methods

Preparation of the patient A simple account of the procedure is given to the patient if he is old enough to co-operate The arms are inspected and a vein of suitable size in the antecubital fossa or forearm which drains into the basilic system is chosen attempts to enter the thorax through the cephalic system are usually unsuccessful The disposition of the screening equipment may allow access to the patient from only one side of the X ray table and this must be remembered in chosing the arm and positioning the patient

Prophylactic systemic penicillin is administered for 48 hours the initial injection preceding the investigation Quinidine sulphate 3 to 6 grains according to age may be given as a prophylactic against supraventricular tachycardia 30 minutes before the commencement in patients who are in sinus rhythm

Sodium amytal 3 to 6 grains is the only sedation necessary for adults and co-operative children in patients with chronic pulmonary disease the dose should not exceed 3 grains In very young and manifestly unco-operative children an appropriate dose of rectal thiopentone is given and this may be supplemented later by intravenous administration through the catheter during the investigation it is best to co-opt the assistance of an anaesthetist for

this purpose. Volatile anaesthetics or intermittent use of oxygen during the investigation will invalidate the results of the blood gas analysis.

Assembly of the apparatus. The operator wears a protective lead apron, sterile mask, gown and gloves.

The instruments are laid out on a sterile trolley. The all-glass sampling syringes are lubricated with sterile liquid paraffin, three drops of heparin added to each, and all air expressed. The four-way tap, which has been autoclaved complete with its mounting arm, is attached to the X-ray table. A transfusion set is assembled with normal saline containing 500 units of heparin per pint and connected to the tap. The saline manometer—autoclaved in a protective glass case—is connected to the tap and filled from the drip bottle, care being taken to exclude all air. A suitable length of sterile polythene tubing fitted with Luer-lock mounts connects the four-way tap to a three-way tap on the electrical manometer; this tubing is flushed through with saline from the drip bottle. The manometer, which is not sterile, is rendered air-free by flushing through with distilled water from its own pressure bottle and the excess is ejected through the three-way tap. This manometer is then ready for balancing and calibration.

The patient lies supine upon a sorbo mattress with both arms free. Orthopnoea may be counteracted by tilting the table.

Introduction of the arterial needle. A small pillow is placed beneath the elbow and the forearm extended. The antecubital fossa is cleansed and draped. The course of the brachial artery is identified by palpation and the site of arterial puncture chosen. The skin and peri-arterial tissues are anaesthetized with a small quantity of 2 per cent procaine. Steadying the artery with the left index finger, the Riley needle is introduced through the skin and plunged boldly into the artery until a spurt of blood from the base of the needle indicates that the lumen has been entered; the blunt stylet is then inserted and the needle gently threaded up the artery and strapped in position. The arm may then be placed unsplinted by the patient's side.

Introduction of the catheter. A stout plywood approximately nine inches wide is placed beneath the patient and projects obliquely from the table edge to provide a convenient support for the arm. The vein is exposed and cleaned in the usual manner. A catheter of suitable size is selected, attached to the four-way tap, and flushed through with saline. The vein is then lifted in a cat-gut sling, incised obliquely, and the catheter inserted with the aid of a small aneurysm needle. A catheter of correct size does not stretch the vein during introduction and will advance freely and painlessly into the thorax; if it is gripped by the vein manipulation will be difficult and painful and it should be discarded forthwith for one of smaller size.

Manipulation of the catheter. The catheter is guided under fluoroscopic control, and it can usually be advanced freely and without subjective sensation into the right atrium. Occasionally the tip may be arrested at the commencement of the innominate vein or pass into the neck via the internal jugular vein at this point; it may enter the contra-lateral innominate vein instead of passing down into the superior vena cava. Should any of these difficulties arise the catheter is withdrawn slightly, the tip redirected by rotation, and again advanced, repeating the manœuvre until the obstruction is by-passed or the false direction corrected.

To enter the inferior vena cava, the tip is rotated towards the posterolateral wall of the auricle so that the catheter will pass in a caudal direction through the inferior vena caval opening.

The right ventricle is entered by rotating the tip so that the catheter may advance

obliquely across the cavity of the right auricle towards the tricuspid valve Once the ventricle has been entered the catheter tip frequently passes to its apex and there becomes entangled in the papillary muscles or trabeculae carneae attempts to enter the pulmonary artery from this position will fail and may damage the endothelial lining and induce ventricular extrasystoles

The infundibular portion of the right ventricle is entered by directing the catheter tip gently against the septum or anterior wall until it turns in a cephalad direction If this manoeuvre fails it should be withdrawn into the right atrium and the tip bounced off the inferior wall until the catheter forms a U within the atrium vigorous rotation



Fig 15-1



Fig 15-2

Fig 15-1 —Catheter in right lung field.

Fig 15-2 —Catheter in left lung field.
Note that the left pulmonary artery arises posteriorly from the main stem

will now flip it through the tricuspid valve with the tip directed towards the infundibulum and it can be advanced without difficulty into the pulmonary artery from this position

The natural curve upon the catheter usually directs it into the right main branch of the pulmonary artery and it can be advanced into the peripheral field of the right lung To enter the left main branch it is withdrawn to the main stem and the tip rotated posteriorly and to the left a manoeuvre which is made difficult by the fully advanced position and the free oscillation of its tip with each cardiac systole

In most investigations the catheter is passed immediately into the pulmonary artery and pressure measurements and blood samples are taken from the ventricle and atrium during its withdrawal When stenosis of the right ventricular outflow tract is present the catheter is not retained in the pulmonary artery longer than is absolutely necessary

Abnormal catheter positions

The coronary sinus The catheter may be inadvertently introduced into the mouth of the coronary sinus which opens, proximal to the medial cusp of the tricuspid valve It will advance freely up the sinus passing into the great cardiac vein until its tip reaches the left border of the heart shadow at the level of the atrial appendage This course may be mistaken for a passage into the infundibulum of the right ventricle and attempts to catheterize the pulmonary artery from this position are, not unnaturally, unsuccessful

The catheter often shows a sharp angulation at the point of entry into the sinus and the portion within the sinus shows a bodily movement towards the apex of the heart with each systole which results from the attachment of the sinus to the atrio-ventricular septum Within the great cardiac vein the tip lies superficially and is sub-epicardial, in contrast to the infundibular position which lies well within the heart shadow These points enable catheterization of the sinus to be recognized immediately, but if doubt is still present a blood sample will show a very low oxygen content and saturation

The left atrium This may be entered via an atrial septal defect or patent foramen ovale, the catheter crosses the heart shadow above the level normally occupied by the tricuspid orifice and its tip will pass to the upper segment of the left border frequently entering the atrial appendage in this position The mean pressure will be equal to or slightly above that in the right atrium and the pressure curve will be atrial in form It is frequently possible to curl the catheter in the left atrium thus delineating its size and position The left ventricle may be entered by directing the catheter tip towards the cardiac apex and retrograde catheterization of one of the pulmonary veins may be achieved by probing the posterior wall of the atrium When the catheter fails to pass spontaneously through an atrial defect which is suspected on clinical grounds attempts must be made to demonstrate its existence, a loop is formed within the right atrium so that the tip lies just above the tricuspid valve and then, by alternately advancing and withdrawing the catheter, the medial wall is explored for a defect When surgical closure is contemplated an assessment of the size and position of the defect will be valuable and for this purpose a catheter with an inflatable balloon mounted on its tip may be passed into the left atrium, the balloon is then distended with diodone and the catheter withdrawn until the defect is occluded, it is then slowly deflated until it is of sufficient size to slip back into the right atrium

The aorta Catheterization of the aorta is usually possible when it arises directly from the right ventricle or over-rides a ventricular septal defect The catheter tip then advances into the upper mediastinum without conforming to the anatomical configuration of the pulmonary arterial tree and will pass into the neck or right arm via the innominate artery or double back upon itself as it negotiates the arch and descends into the thoracic aorta, pressure records and blood samples will confirm its position Entry of the aorta from the pulmonary artery via a patent ductus arteriosus is also possible and most frequently accomplished when the duct is large and associated pulmonary hypertension has reduced or reversed the shunt As the catheter tip negotiates the duct it will appear to form a tight loop which is directed backwards and medially within the main stem of the pulmonary artery but when advanced further its free passage down the thoracic aorta into the abdomen will reveal what has occurred When the pulmonary arterial and aortic pressures are identical it is sometimes difficult to determine whether the catheter has entered the aorta via a ventricular septal defect or a patent ductus, in the former instance the right subclavian and carotid arteries can be entered and the tip will be seen to pass backwards and laterally as it negotiates the arch

Other abnormal positions With anomalous systemic venous drainage the catheter may pass directly into the left atrium via the superior or inferior vena cava The catheter may enter the right lung field from the right atrium via an anomalous pulmonary vein When the left arm is used the catheter tip may be arrested at the level of the aortic arch by a persistent left superior vena cava and if this vessel is entered the tip will pass sharply downwards and then turn obliquely across the heart shadow to enter the right atrium via the coronary sinus it is rarely possible to advance further and the true state of affairs may be recognized by the characteristically tortuous course taken Anomalous pulmonary veins may also drain directly into the superior vena cava and should be suspected when this vessel is aneurysmally dilated



Fig 15-3



Fig 15-4

Fig 15-3 —Catheter in right ventricle with its tip just below the pulmonary valves.

Fig 15-4 —Catheter in coronary sinus and great cardiac vein. Note the position and direction of catheter tip.

Taking blood samples

The catheter is connected to the sampling arm by adjustment of the four way tap and a few ml of blood diluted with saline from the catheter withdrawn and discarded five to ten ml of blood are slowly withdrawn into an air free heparinized syringe a small quantity of clean mercury introduced and the syringe then sealed and vigorously agitated to ensure complete mixing with the heparin The tap and catheter are flushed clean with heparinized saline Arterial samples are obtained in the same manner but flushing of the needle is unnecessary and it may be kept clean by dipping the stylet in hydrogen peroxide before re insertion

When estimating the cardiac output by the Fick principle the mixed venous sample is

taken during expired air collection and the arterial sample immediately the latter is complete Blood samples obtained from the pulmonary artery, right heart chambers and great veins for comparison of their oxygen contents in order to establish the site and size of a left-to-right shunt must be taken in rapid succession to reduce errors arising from spontaneous fluctuations in the haemo-dynamic equilibrium , commencing with the pulmonary arterial sample, each successive sample is obtained by withdrawing the catheter tip swiftly to the appropriate position using the pressure pulse record as a guide to the position of the pulmonary and tricuspid valves In cyanotic congenital heart disease the right heart and systemic arterial samples must be taken simultaneously to avoid the same error

Blood gas analysis is performed as soon as possible after sampling and if there is any delay the syringes should be stored in a refrigerator or iced water The manometric blood gas analysis technique of Van Slyke and Neill gives the most accurate results in trained hands

Pressure measurement

Appropriate adjustment of the four-way tap will connect the catheter to saline or electrical manometers The saline manometer must be well primed beforehand so that its contents are discharged into the catheter until the level becomes stationary , reflux of blood up the catheter will occur if it is passed from a low- to a high-pressure chamber with this manometer in circuit The catheter may be manipulated with the electrical manometer in circuit without this risk.

The pulmonary capillary pressure is obtained by advancing the catheter tip into the lung field until it completely occludes one of the smaller pulmonary arteries A satisfactory " wedge " may be obtained in any segment of either lung and is recognized by resistance of the tip to withdrawal and a blood sample from the site which is fully oxygenated The form of the pulmonary " capillary " pressure record is usually distinctive and this provides another valuable guide to correct positioning. In patients with long-standing pulmonary hypertension *it is occasionally impossible to achieve a satisfactory " wedge "* owing to extensive obliteration of the arterial bed

The most satisfactory right ventricular pressure records are obtained with the catheter tip lying freely within the main cavity and records from the outflow tract are frequently distorted by occlusion of the tip and ventricular extrasystoles Right atrial pressures are measured from the main cavity of the chamber

All pressure records will show a slow rhythmic variation of the base line synchronous with the respiratory cycle of 5 to 10 mm Hg amplitude which is the reflection of intrathoracic pressure change , exaggeration of this respiratory fluctuation is a manifestation of increased rigidity of the lungs which may be the result of oedema, inflammation or fibrotic change

When the investigation has been completed the catheter is slowly withdrawn and the skin incision closed with a stitch which encircles the unligated vein The arterial needle is removed and the site of the puncture gently occluded with one finger until oozing ceases.

Complications of cardiac catheterization

Cardiac arrhythmias. Ectopic ventricular beats occur most frequently when the catheter tip is passing through the right ventricular outflow tract but they rarely give rise to subjective sensations Ectopic auricular beats may occur when the catheter is looped within the right atrium and occasionally paroxysms of auricular tachycardia or fibrillation may be provoked in this way particularly in patients with mitral disease Monitoring

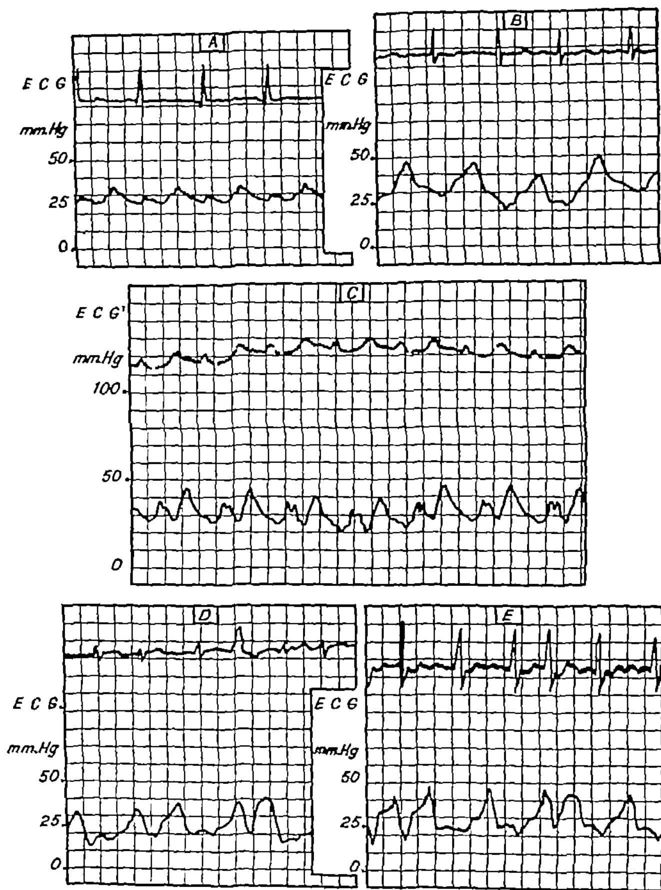


Fig 15-5

Fig 15-5 Typical pulmonary "capillary" pressures in mitral valve disease Wedge pressures recorded with simultaneous electrocardiograms.

A Tight mitral stenosis in sinus rhythm Not a and v waves with slow "y" descent
B Tight mitral stenosis with atrial fibrillation Note solitary "v" wave with slow "y" descent.
C Mitral stenosis with incompetence in sinus rhythm
D and E Two examples of pure mitral incompetence with atrial fibrillation. Note solitary "v" wave with rapid "y" descent the form of the wave is modified by the duration of preceding diastole

with continuous electrocardiography is advisable during manipulation of the catheter and any ectopic beats should be reported. Prophylactic quinidine does not appear to reduce the incidence of catheter-induced arrhythmia. If an arrhythmia becomes established the investigation should be terminated and appropriate measures taken to restore sinus rhythm.

Endocardial damage. Careful post-mortem examination of the right auricle and ventricle of subjects who have died shortly after, but not consequent upon, cardiac catheterization has not revealed evidence of endocardial damage. The occasional development of transient right bundle branch block and the demonstration of injury currents with the electrode-catheter indicate that minor trauma does occur, particularly during passage of the catheter tip through the right ventricular outflow tract. To reduce these risks the softest and smallest catheter compatible with adequate manipulation and blood sampling should be chosen; the catheter tip must lie within the right ventricle no longer than is necessary for sampling and pressure recording. The patient must not be moved when it is in this position for there is risk of impaling the heart in this way. These risks are greatest with a vigorously contracting and hypertrophied right ventricle and special care should be taken in such cases.

Retrograde catheterization of the coronary sinus with wedging in a tributary vein has been followed by substernal pain, cardiographic evidence of myocardial ischaemia and pericardial friction; recognition of coronary sinus entry by the methods outlined will prevent this risk.

Embolism. Fatal arterial embolism has followed *catheterization of the left ventricle* and was found to have arisen from a mural thrombus on an area of endocardial damage. The risk of *systemic embolus is greatest in cyanotic* congenital heart disease and transient hemiparesis has occurred twice in the author's experience, both cases recovering completely within a few hours.

Pulmonary infarction. Wedging of the catheter in one of the pulmonary arteries to obtain the pulmonary "capillary" pressure may damage the intimal lining with subsequent thrombosis and pulmonary infarction. The risk is undoubtedly greater when the vessels have undergone atherosclerotic degeneration, an occurrence most frequently found in association with long-standing pulmonary hypertension; retrograde spread of the thrombus may then so increase the already abnormally high vascular resistance that right heart failure develops. Gentle manipulation of the catheter, wedging for the shortest possible time and oral anticoagulants in susceptible patients will all help to reduce the incidence of this complication. Local venous thrombosis at the site of incision rarely gives rise to more than local discomfort and its extent is probably limited by leaving the vein unligated.

Pyrexia. Infection is avoided by prophylactic systemic penicillin and a rigorous aseptic technique. Pyrexia and rigors following the procedure may be prevented by thorough cleansing of the catheter and taps with hydrogen peroxide before sterilization.

Interpretations of cardiac catheterization findings

Cardiac output

Normal values. The cardiac output is estimated by use of the Fick principle thus,

$$\text{Cardiac output (litres per minute)} = \frac{\text{Oxygen consumption in c.c. per minute}}{\text{Arterio-venous oxygen difference in c.c. per litre of blood}}$$

The figure for arterio-venous oxygen difference is obtained by subtracting the oxygen content of the mixed venous blood from the oxygen content of the arterial blood These values are normally expressed in c c of oxygen per 100 ml of blood. The cardiac output is normally determined with the subject at complete rest and in a basal state and if these conditions are observed the oxygen consumption is an expression of the basal metabolic rate and will be proportionate to the age sex and surface area It is therefore necessary to express the cardiac output in relation to the metabolic needs in order to obtain a figure which may be used for comparison and this is done by relating it to body surface—cardiac output in litres per minute per square metre of body surface the so-called cardiac index or by relating it to oxygen consumption—cardiac output in litres per minute for every 100 c c of oxygen absorbed.

Provided that the oxygen consumption of the subject lies within the normal range for basal metabolic requirements the arterio venous oxygen difference—when expressed as a reciprocal—is a measure of the circulation rate In normal subjects at rest in the supine position the arterio-venous oxygen difference has an average value of 4 4 volumes per 100 ml. of blood with a range of 3 5 to 6 0 volumes per 100 ml When the blood has a normal haemoglobin content of 14 5 grammes per 100 ml the oxygen capacity will be approximately 20 0 volumes per 100 ml. and an arterio-venous oxygen difference of 4 4 volumes per 100 ml will be equivalent to an oxygen utilization of 22 per cent thus

$$\text{Oxygen utilization} = \frac{\text{arterio venous oxygen difference}}{\text{oxygen capacity of blood}} = \frac{4\ 4}{20{\cdot}0} = 22\ 0 \text{ per cent}$$

Normal arterial blood has an oxygen saturation between 97 and 94 per cent and therefore the mixed venous blood oxygen saturation will lie between 75 and 72 per cent with a range of 79 to 64 per cent

The cardiac output in the normal subject when resting supine usually lies between 2 5 and 3 5 litres per minute per square metre of body surface a truly basal state is rarely achieved under the conditions of this investigation and the value obtained depends greatly upon the temperament of the patient and the degree of sedation employed

Abnormal values Estimation of the resting output has proved a disappointingly crude index of cardiac function patients with manifest symptoms and signs of failure frequently have resting outputs within the normal range whilst the output of those with severe congestive failure rarely fall below half the average normal value unless death is imminent Nevertheless application of the Fick principle has established a clear distinction between the low-output failure of degenerative hypertensive and rheumatic heart disease on the one hand and the high-output failure of anoxic cor pulmonale thyrotoxicosis anaemia beri beri and systemic arterio venous aneurysm on the other The resting cardiac output is usually determined in order to obtain the essential data from which the *size of shunts* the pulmonary vascular resistance the degree of valvular obstruction and the work of the heart may be calculated

Shillingford and Korner s demonstration of the frequent occurrence of significant tricuspid incompetence in right ventricular failure makes invalid many of the published figures for right ventricular work in mitral stenosis for these data are based upon the uncertain premise that all work done may be estimated from the forward flow alone McMichael and Shillingford point out that severe functional tricuspid incompetence may be the primary cause of fixed low-output failure and under these conditions a very high work level may be maintained by the right ventricle despite the sub normal forward flow These observations may serve to explain the anomalous observations that successful valvotomy for

mitral stenosis increases circulatory efficiency only at the cost of increased right ventricular work

Exercise increases the oxygen requirements of the body and this is met in part by a rise in the cardiac output and in part by increased extraction of oxygen from the blood with a consequent fall in mixed venous oxygen saturation These changes represent the summation of a complex readjustment of regional blood flows to meet the altered oxygen needs In established cardiac failure the output of the heart is relatively fixed and fails to rise in response to exercise so that the greater demand for oxygen can be only partly met by redistribution of flow and increased oxygen utilization Donald and his colleagues have developed an elegant technique of continuous sampling of venous and arterial blood and expired air which demonstrates the minute-to-minute changes in total and regional blood flow in response to exercise upon a horizontal bicycle ergometer. They have studied normal volunteers and patients with low-output failure and hyperkinetic states and their findings, which demonstrate the intricate inter-relationships between these parameters, will repay careful study Unfortunately their technique is too elaborate and time-consuming for routine diagnostic use

Interpretation of intracardiac pressures

All pressures, estimated by saline or electrical manometers, are conveniently expressed in millimetres of mercury with a zero reference point on the horizontal plane passing through a point 5 0 cm dorsal to the angle of Louis

Normal values All pressures will reflect the cyclical variation of intrathoracic pressure due to respiration and measurements are made at the end of a normal quiet expiration The normal right auricular pressure is 0 ± 5 mm Hg The right ventricular diastolic pressure, which is measured at the end of the diastolic phase, is normally equal to the right atrial pressure, the normal right ventricular systolic and pulse pressures vary between 15 and 30 mm Hg with an average value of 20 millimetres The pulmonary arterial systolic pressure equals that in the right ventricle and the diastolic pressure varies according to the systolic level and the heart rate usually lying between 8 and 15 mm Hg The mean pulmonary arterial pressure does not normally exceed 20 mm Hg The normal pulmonary "capillary" wedge pressure does not normally exceed 10 mm Hg and is usually below this value With normal cardiac function neither the pulmonary capillary nor the pulmonary arterial pressures show any significant rise in response to light exercise of the legs

Pulmonary hypertension There are three possible causes for abnormal elevation of the pulmonary arterial pressure which may act singly or in combination increased filling pressure in the left atrium, increased resistance to flow through the pulmonary vascular bed, and increased pulmonary blood flow

Increased left atrial pressure is transmitted to the pulmonary bed and recognized there by elevation of the pulmonary "capillary" pressure estimated by the wedge technique This rise in pulmonary capillary pressure is the earliest and most sensitive index of left ventricular failure and of obstruction to flow through the mitral valve

In mitral stenosis the pulmonary "capillary" pressure reflects the rise in left atrial pressure which is necessary to maintain the observed cardiac output through the narrowed valve during the filling phase of ventricular diastole, resting values of 15 to 30 mm Hg are found in disabled patients and levels exceeding 35 mm Hg at rest herald the onset of pulmonary oedema The observed level of the pulmonary "capillary" pressure in pure mitral stenosis is a function of the size of the mitral orifice, the volume of the forward flow (i e cardiac output) and the diastolic filling time of the left ventricle, Gorlin and his col

leagues have devised a formula which will estimate the actual size of the mitral orifice in pure stenosis on the basis of this interrelationship Exercise causes a further rise in pulmonary capillary pressure and mean values of 50 mm Hg or more are not infrequently recorded levels of this order may occur without any measurable increase in the cardiac output presumably because the associated tachycardia limits flow through the valve by shortening of the diastolic filling time The pulmonary capillary pressure in tight mitral stenosis is so critically balanced by the cardiac output diastolic filling time and the pressure/volume relationships of the left atrium and pulmonary veins that spontaneous fluctuations in the resting level are often observed Mitral incompetence and mitral stenosis with incompetence of sufficient severity to be disabling are also associated with abnormal pulmonary capillary pressures and the level observed at rest and its response to exercise has proved valueless in deciding whether the stenosis is predominant or whether the condition will be amenable to mitral valvotomy For this reason attention was turned to the form of the pulmonary capillary pulse wave in the hope that this would provide the necessary information on the type of valvular lesion With normal sinus rhythm two positive waves occur in the capillary record with each cardiac cycle an a wave of atrial systole and a V wave of venous stasis Earlier claims that loss of the normal x dip between a and v wave and that v waves of great amplitude were the signs of significant incompetence have both proved to be false The most promising approach has come from the work of Wood and Owen who have related the speed of descent of the v wave that is the y dip to the rate of filling of the left ventricle this association is also dependent upon the pressure/volume relationships of the left atrium and this has been allowed for by incorporating the absolute pressure level in their formula This method requires a good, undamped capillary record which is not always attainable

The term passive pulmonary hypertension is employed when an increased pulmonary arterial pressure is due solely to raised left atrial and pulmonary venous pressures, the pulmonary arterial—pulmonary capillary pressure gradient which is a function of the pulmonary vascular resistance will be normal The pulmonary vascular resistance (PVR) is determined by Aperia s formula

$$PVR = \frac{PAP - PCP \text{ gradient in mm}}{\text{cardiac index (litres/minutes)}} \text{ Hg} \times 79\ 92$$

expressed in dynes per cm^{5} per second^{-5}

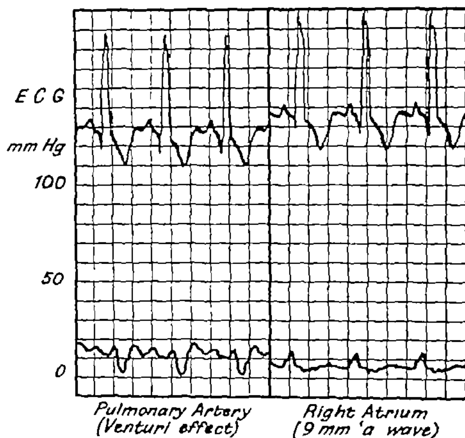
This formula which was designed to express the resistance of rigid tubes to steady rates of flow can give only a very approximate measurement of the impedance offered by the elastic pulmonary vessels to the phasic flow of ventricular ejection Conclusions which are based upon minor variations in the pulmonary vascular resistance calculated in this way must be treated with reserve The normal value for the PVR does not exceed 150 dynes Severe pulmonary hypertension is invariably a sign of increased vascular resistance which may equal or exceed that normal for the systemic bed The etiology of such abnormal increases is still obscure Persistence of the foetal type of pulmonary arteriole reflex spasm of the arterial bed in response to rise in left atrial pressure thrombo-embolic obliteration and pulmonary arteriolitis have all been implicated Surgical relief of tight mitral stenosis has been followed by substantial reduction in the pulmonary vascular resistance injections of acetyl choline directly into the pulmonary artery will produce a transient reduction in resistance whilst adrenalin and nor adrenalin cause a transient rise These findings prove that active contraction of the pulmonary arterial tree plays a part in the increased resistance in this condition A high pulmonary vascular resistance greatly modifies the

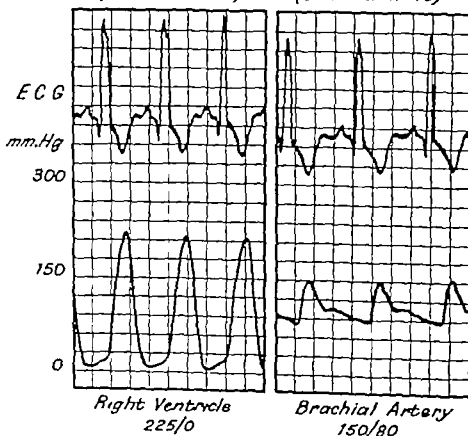
pattern of the underlying cardiac condition, in mitral stenosis this pre-capillary obstruction frequently prevents the development of pulmonary oedema, when the resistance is further increased by superimposed thrombo-embolic obliteration, relief of the primary mitral obstruction may not benefit the patient who succumbs slowly from a chronic cor pulmonale Increased resistance accompanying congenital lesions such as patency of the ductus arteriosus ventricular and atrial septal defects will diminish the left-to-right shunt or reverse its direction so that the pattern of the Eisenmenger's syndrome will emerge, attempts at repair then carry the risk of death from acute or chronic right heart failure

An increase in the pulmonary blood flow will not cause a substantial rise in the pulmonary arterial pressure when the vascular resistance is within the normal range Nevertheless, it is essential to determine the blood flow in order to attempt an estimation of the vascular resistance

Pulmonary stenosis The systolic pressures in the pulmonary artery and right ventricle are normally equal, a difference between the two levels indicates obstruction to the right ventricular outflow tract which is due to stenosis of the pulmonary valve or infundibulum When the ventricular septum is intact the right ventricle discharges the whole of its output through the stenosis and the systolic pressure which is necessary to achieve this ejection is a valuable index of the severity of the obstruction, levels exceeding 100 mm Hg indicate severe stenosis If, however, a ventricular septal defect co-exists, as in the tetralogy of Fallot, a variable proportion of the right ventricular blood will be discharged directly into the aorta, the right ventricular systolic pressure will then equal that in the systemic circulation and the severity of the stenosis can only be determined indirectly from the proportion of mixed venous blood which enters the lungs It is clear, therefore, that with severe pulmonary stenosis a significant difference between the right ventricular and brachial arterial systolic pressures indicates an intact ventricular septum It is often difficult to differentiate between valvular and infundibular stenosis, this is most commonly valvular when the septum is intact but valvular and infundibular stenosis, alone or in combination, are found in the tetralogy of Fallot An attempt should be made to identify the site by slow withdrawal of the catheter from the pulmonary artery, observing the position of the catheter tip when a ventricular pulse curve is first obtained on the manometric record, with valvular stenosis the fused cusps are projected into the pulmonary artery and the pressure change will occur when the tip still lies within the shadow of the pulmonary artery, whilst with infundibular obstruction the change is observed with the tip in the outflow tract of the ventricle Unfortunately the observations are frequently equivocal because obstruction of the tip within the outflow tract may give the impression of an infundibular obstruction To overcome this difficulty Emslie-Smith, Lowe and Hill have used an electrode on the tip of the catheter and claim that the intracardiac cardiogram obtained will accurately identify the position of the pulmonary valve ring, pressure change above this level indicates valvular stenosis, and below it infundibular stenosis.

Right ventricular failure The end-diastolic pressure within the right ventricle, measured after a normal quiet expiration, normally lies at or slightly below the manometric zero level, any significant increase indicates a raised filling pressure and, therefore, ventricular failure This is usually accompanied by dilatation of the chamber. exercise will cause a further rise in pressure and the response of the cardiac output will be subnormal Failure most commonly results from increased work due either to primary left heart failure, increased pulmonary vascular resistance or pulmonary stenosis this will be reflected in an increased systolic and pulse pressure Primary failure of the right ventricle, such as may occur in constrictive pericarditis, amyloid heart disease and fibroelastosis, is not usually associated





Arterial oxygen saturation 98%
Cardiac index 2 21 litres/min/sq metres

Fig 15-6 —Typical findings in isolated pulmonary valvular stenosis.

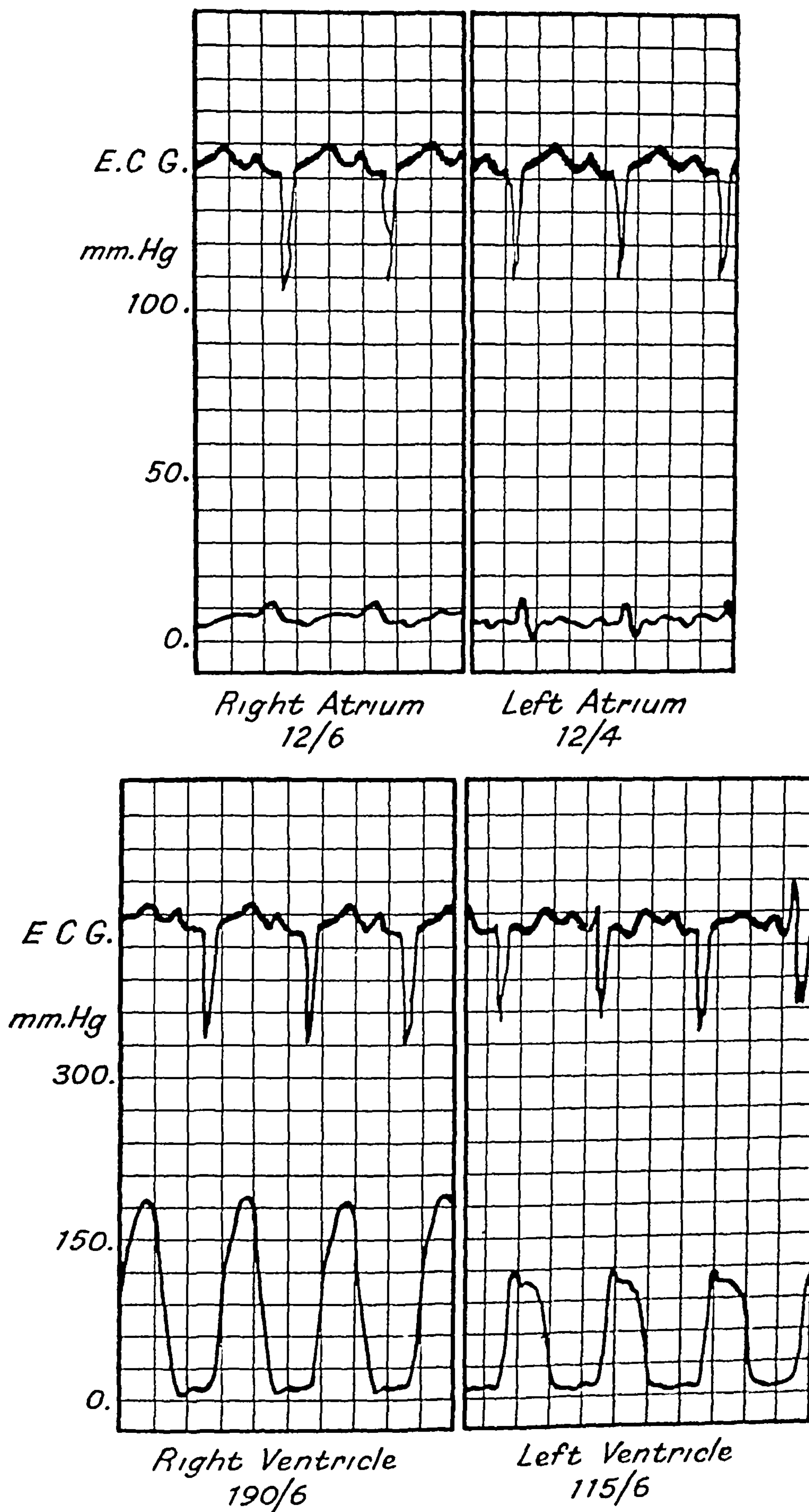
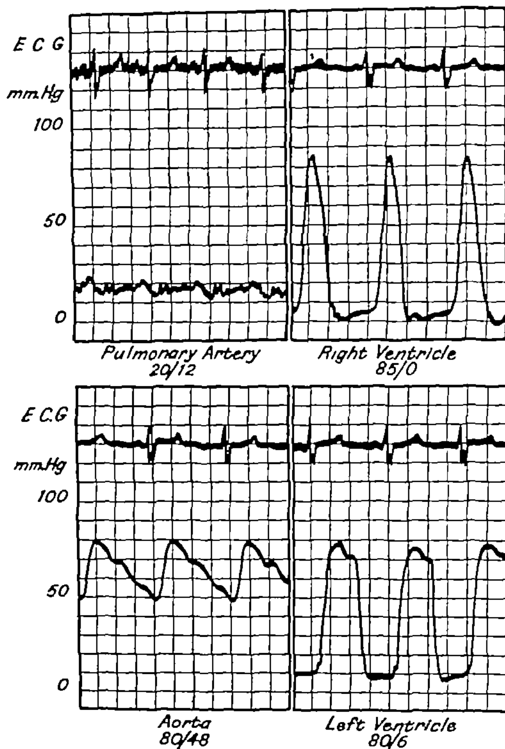


FIG. 15.7.—Typical findings in pulmonary valvular stenosis with atrial septal defect.



Oxygen saturations

SVC 63% Right atrium 69% Right ventricle 71%
Pulmonary artery 68% Aorta 90%

Fig 15 8 —Typical findings in pulmonary valvular stenosis with ventricular septal defect

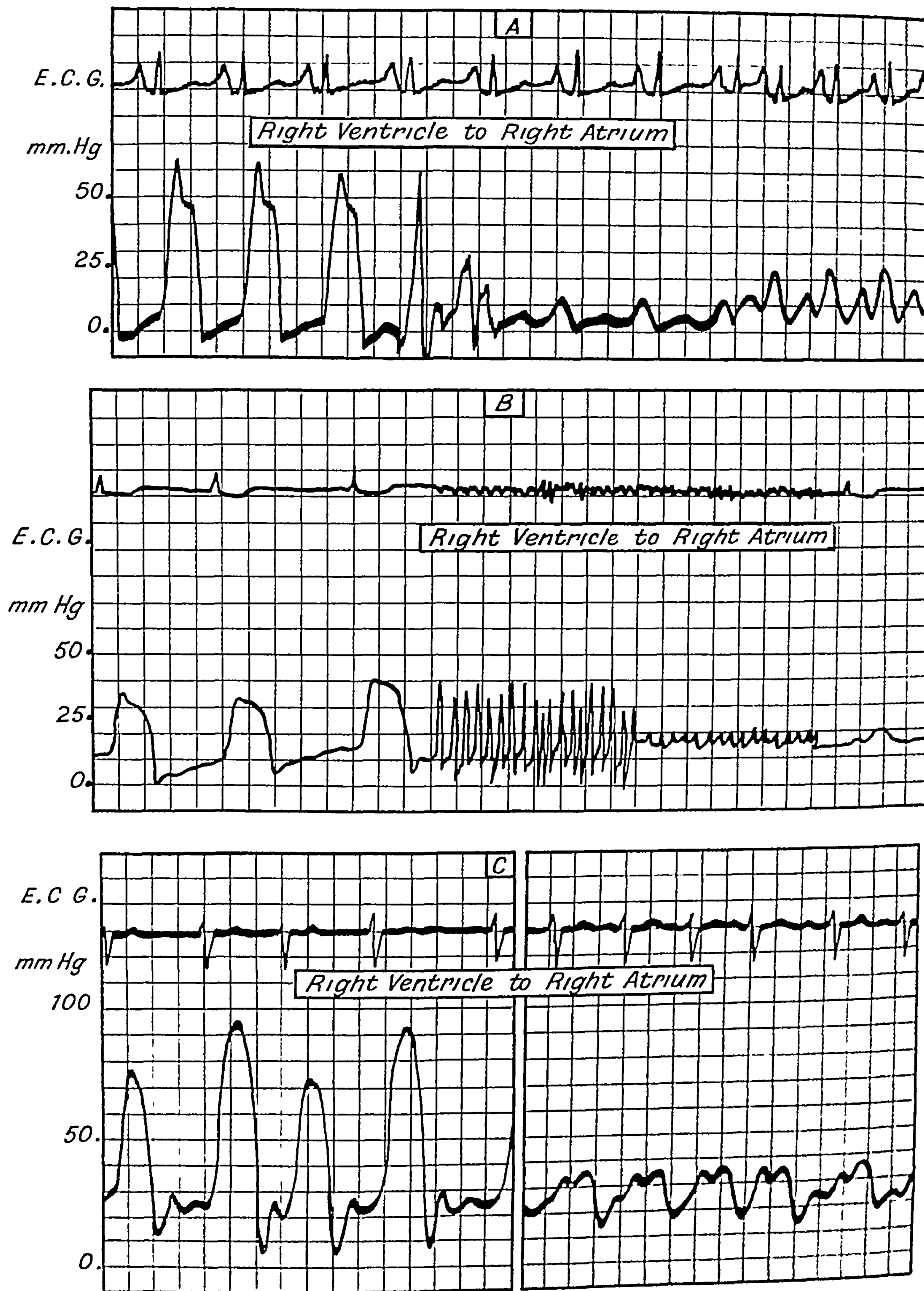


Fig. 159. Typical right heart pressures in tricuspid valve disease. The catheter has been withdrawn from ventricle to atrium with continuous recording. Simultaneous electrocardiograms.

A. Tricuspid stenosis in sinus rhythm. Note slow rise in right ventricular diastolic pressure with absence of the "a" wave [illegible] "a" wave in right atrial pulse which is increased by exercise.
B. Tricuspid stenosis with atrial fibrillation. Note slow rise in ventricular diastolic pressure with gradient across the valve [illegible]
C. Tricuspid incompetence with atrial fibrillation. Note early diastolic dip in ventricular record with rapid filling [illegible] wave [illegible] in right atrial record.

with increased work under these conditions diastolic hypertension will be associated with a normal or subnormal pulse pressure This is the pattern seen most characteristically in

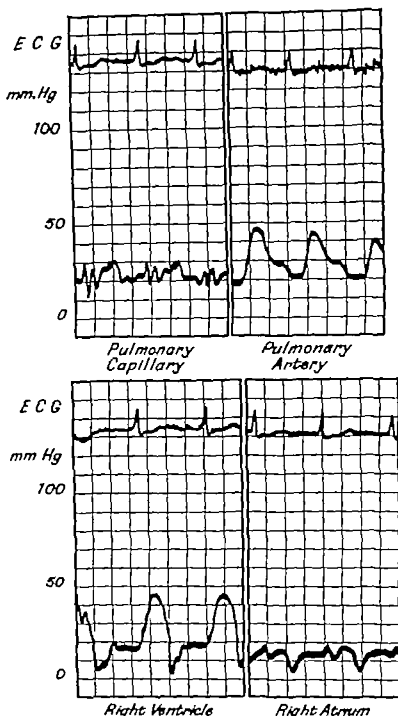


FIG 15-10 —Typical right heart pressures in constrictive pericarditis. Simultaneous electrocardiograms.

Note parallel rise in the pulmonary capillary and right atrial pressures with the dominant "y" dip in both records the early diastolic dip in the right ventricular record rises steeply to a diastolic plateau and the end-diastolic pressure in the pulmonary artery equals that in the right ventricle Pulmonary arterial and right ventricular pulse pressures are normal.

constrictive pericarditis where right atrial and pulmonary capillary pressures show a parallel rise which reflects the increase in filling pressure of the constricted ventricles necessary to maintain an adequate stroke volume and cardiac output

Diastolic hypertension is usually accompanied by a transient dip of the systolic pulse wave to zero pressure level in the first phase of diastole before filling commences thus

pattern may be seen in right ventricular failure from any cause but is most constant in constrictive pericarditis where the "y" descent becomes the most prominent wave in the venous pulse

Tricuspid valve disease Stenosis of this valve creates a forward pressure gradient across the orifice during the diastolic filling phase which may be demonstrated by pressure recording during slow withdrawal of the catheter tip from the right ventricle A more accurate measurement of the pressure gradient will be obtained by use of a double lumen catheter attached to a differential manometer but this method is not yet in routine use With normal atrial contraction, the right atrial "a" waves will be exaggerated occasionally exceeding 10 mm of Hg Tricuspid incompetence usually accompanies stenosis, and functional incompetence is a common complication of right ventricular failure Gross incompetence will modify the right atrial pulse but lesser degrees of regurgitation are not readily demonstrated at rest, the normal negative "x" dip disappears and may be replaced by a large positive pressure wave commencing during ventricular systole, fusing with the preceding "a" wave, if this is present, and with the "v" wave which follows The height of this systolic wave depends upon the degree of regurgitation and the pressure/volume relationships within the right atrium and great veins, exercise increases its amplitude and is a valuable confirmatory test in doubtful cases When there is significant tricuspid disease the right atrium will be abnormally large, the tricuspid orifice will come to occupy a position on its medial wall and entry of the right ventricle may be difficult owing to looping of the catheter within this enlarged chamber

Recognition and localization of arterio-venous shunts

Congenital atrial or ventricular septal defects, patency of the ductus arteriosus and anomalous pulmonary venous drainage may be responsible for the passage of fully oxygenated blood from the left side into the right heart chambers or pulmonary artery with recirculation through the lungs Catheterization of the heart enables the site and size of such shunts to be determined with fair accuracy Blood samples are withdrawn from the pulmonary artery, the infundibulum and main cavity of the right ventricle, right atrium, superior vena cava and the brachial artery, and the oxygen content of these samples is estimated and compared Such samples taken from a normal heart may show a variation of oxygen content which is due to incomplete mixing of the venous blood before it reaches the pulmonary artery, and therefore any observed increase in oxygen content of the blood passing through the right heart must exceed the limits of this normal variability before an arterio-venous shunt can be diagnosed with confidence This normal variability in oxygen content is greatest between superior vena caval and right atrial samples, the inferior vena cava is an unreliable source for this purpose because stream-lining of oxygen-rich blood from the renal veins and oxygen-poor blood from the hepatic veins occurs Mixing is usually complete within the right ventricle and, in the normal heart, samples taken from above and below the pulmonary valves rarely show any difference An arterio-venous shunt into the right atrium may be presumed if the oxygen contents of right atrial, right ventricular and pulmonary arterial blood exceeds that of the superior vena cava by more than 2 0 volumes per 100 ml An arterio-venous shunt through a ventricular septal defect may be presumed if the oxygen contents of right ventricular and pulmonary arterial samples exceed that from the right atrium by more than 1 0 volume per 100 ml Small defects which lie high in the membranous septum may only increase the oxygen content of the infundibular and pulmonary arterial samples

An arterio-venous shunt through a patent ductus arteriosus or aorto-pulmonary fistula

may be presumed if the oxygen content of pulmonary arterial blood exceeds that from the infundibular portion of the right ventricle by more than 0 5 ml per 100 ml

Differentiation between a patent ductus and high ventricular septal defect may be difficult when increased vascular resistance has caused pulmonary hypertension with a decrease in the size of the shunt or its reversal Significant pulmonary incompetence may also add to the confusion in patent ductus by allowing a reflux of arterial blood into the right ventricle When pulmonary vascular resistance has rendered the shunt small or insignificant the pulmonary and systemic arterial pressures will be virtually equal and will rise and fall together exercise will cause a significant fall in the arterial oxygen saturation due to reversal of shunt

Having established the presence of an aorto-pulmonary or ventricular communication in this way the site may be demonstrated by passing the catheter through the defect or failing this by selective angiocardiography or retrograde aortography With reversed shunt through a patent ductus the right brachial arterial sample will contain more oxygen than the femoral arterial sample since it lies proximal to the shunt With ventricular septal defect the saturations will be the same Bi-directional shunts are common in ventricular septal defect with pulmonary hypertension but do not occur in patent ductus as an isolated defect

Anomalous pulmonary venous drainage and atrial septal defects cannot be differentiated by blood gas analysis Atrial septal defect may have its position and size demonstrated by passing a catheter through it into the left atrium Confusion may still arise if the two conditions are associated which is not infrequently the case Anomalous veins which drain from the right lung into the right atrium are best recognized by retrograde catheterization entering the heart from the right side facilitates exploration of the postero-lateral wall of the atrium for such vessels Total pulmonary venous drainage into the superior vena cava is recognized by a superior vena caval oxygen saturation which exceeds that of the systemic arterial blood sample Anomalous left pulmonary veins which drain into the right atrium via the coronary sinus will raise the oxygen saturation of the coronary venous blood above its normal very low level of 10 to 20 per cent the rare congenital arterio-venous fistula of the coronary circulation sometimes confused with a patent ductus or ruptured aortic sinus has the same effect on coronary sinus blood Rupture of the right aortic sinus combines the clinical signs of an aortic fistula with catheter evidence of a shunt into either the right atrium or right ventricle.

The size of an arterio venous shunt is conveniently expressed as a percentage of the orthodox systemic blood flow which is given by the formula

(4) Total pulmonary blood flow (T P.B F) $= \frac{\text{S A} - \text{M V}}{\text{P V} - \text{P A}} \times 100$ per cent of systemic blood flow

Arterio venous shunt = (T P B.F − 100) per cent of systemic blood flow (Where these symbols represent the oxygen contents of blood from systemic artery (S.A) mixed venous blood (M V) taken from the chamber or great vessel proximal to the site of the communication pulmonary vein (P V) and pulmonary artery (P A)) When the shunt is unidirectional the pulmonary venous and systemic arterial contents will be identical If it is bi-directional the arterial sample will contain some venous blood and, failing direct catheterization of a pulmonary vein the pulmonary venous content is assumed to be 96 per cent of the oxygen capacity The absolute size of the shunt is readily calculated from the orthodox systemic blood flow which is determined in the usual way

Shunts into the right atrium cannot be calculated with any accuracy because the superior

vena cava is an unreliable source of mixed venous blood and the normal difference in oxygen content of blood from here and the right atrium, which may be 2 0 volumes per cent, precludes the recognition of small shunts Similarly, in patent ductus mixing of the arterial and venous blood is incomplete within the main pulmonary arteries and any error due to this source is exaggerated by the very low arterio-venous oxygen differences

Recognition and localization of venous-arterial shunts

A proportion of the venous blood returning to the heart may enter the systemic circulation without perfusion of the pulmonary capillaries When this occurs there will be persistent central cyanosis with reduced arterial oxygen saturation and secondary polycythaemia The severity of this venous-arterial shunt is conveniently expressed by the proportion of the mixed venous blood which passes through the lungs—that is, the effective pulmonary blood flow (E P B F)—which is given as a percentage of the orthodox systemic blood flow (S B F) by the formula

$$(5) \qquad \text{E P B F} = \frac{\text{S A} - \text{M V}}{\text{P V.} - \text{M V}} \times 100 \text{ per cent of S B F}$$

Shunt = (100 − E P B F) per cent of systemic flow The absolute size of these flows is readily calculated from the systemic blood flow which is estimated in the usual way Bi-directional shunts are calculated by application of formulae (4) and (5)

Severe disability is usually present when the resting effective pulmonary blood flow is less than 60 per cent of the systemic flow , during exercise there is a further reduction in the proportion of venous blood entering the lungs

The error in calculating the effective pulmonary blood flow is usually small because the high arterio-venous differences which accompany sub-normal flow rates make variations in oxygen content due to inadequate mixing of less significance than in arterio-venous shunts where arterio-venous differences are low The effective pulmonary blood flow calculated thus represents all venous blood reaching the lungs directly via the pulmonary artery and indirectly through anastomotic vessels from the systemic circulation and it is impossible to determine the relative contribution from these two sources

The site of the venous-arterial shunt may be recognized by catheterization of the heart, aided, if necessary, by a general or selective angiocardiogram

The tetralogy of Fallot, commonest form of cyanotic heart disease surviving to childhood and adolescence, presents with pulmonary stenosis and equal systolic pressures in the right ventricle and systemic arteries , the aorta can be catheterized directly from the right ventricle in a considerable proportion of these cases

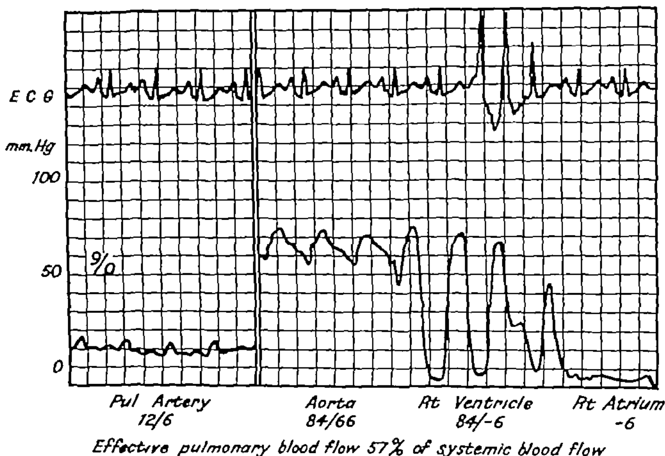
Pulmonary stenosis with atrial septal defect, most readily confused with tetralogy of Fallot, is differentiated by the dissociation between systolic pressure levels in right ventricle and a systemic artery—which excludes a ventricular septal defect—and by the demonstration of an atrial septal defect with a reduced oxygen saturation of left heart blood samples of the same order as that obtained from a systemic artery

Tricuspid atresia is recognized by failure to enter the right ventricle and demonstration of an atrial septal defect with right to left shunt, the reduced oxygen saturation of the left heart blood samples being of the same order as that obtained from a systemic artery

Transposition of the great vessels may be suspected if the aorta is entered from the outflow tract of the right ventricle, but confirmation depends upon entry of a pulmonary artery through a ventricular septal defect and demonstration that the pulmonary arterial

sample has a higher oxygen content than that from the aorta Failure to identify the pulmonary artery makes it difficult to differentiate between transposition of the great vessels and pulmonary atresia or common truncus arteriosus

A common single atrium may be recognized by its size freedom to enter both ventricles from the chamber and a bi-directional shunt A common single ventricle is recognized



Oxygen saturations	
Pul Artery	65%
Rt Ventricle	67%
Rt Atrium	60%
Aorta	80%

FIG 15-11 —Typical findings in the tetralogy of Fallot

by its size the catheterization of both pulmonary artery and aorta from the same outflow tract and a bi-directional shunt this condition is not infrequently associated with pul monary stenosis and may be confused with the tetralogy of Fallot it should be suspected if the blood gas analysis shows any significant left to-right shunt which will be due to ventricular mixing In the tetralogy of Fallot the shunt is almost wholly right to left

Venous arterial shunts may be secondary to increased pulmonary vascular resistance associated with atrial and ventricular septal defects and patency of the ductus arteriosus The differentiation of these three forms of the Eisenmenger s syndrome has been discussed previously

Pulmonary arterio venous aneurysm and anomalous drainage of the inferior vena cava

into the left atrium are two causes of a persistent venous-arterial shunt which will be associated with normal catheter findings in the right heart

Occasional difficulty may arise in differentiating between chronic pulmonary disease and congenital heart disease as the cause of reduced arterial oxygen saturation Inhalation of 50 per cent oxygen will lift the arterial oxygen saturation rapidly to the normal range in chronic pulmonary disease whilst it will have little effect upon a saturation which is reduced by venous admixture Primary and secondary polycythaemias may be differentiated in case of doubt by estimation of the arterial oxygen saturation which will be normal in polycythaemia vera

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CHAPTER 16

CONGENITAL ACYANOTIC HEART DISEASE

In this group, ductus arteriosus and coarctation of the aorta represent the conditions most frequently referred for surgical correction and most amenable to operation Increasingly, surgery is being employed in the treatment of atrial septal defects and pure pulmonary valve stenosis These are serious lesions with a bad prognosis in most patients Abnormalities of the aortic arch (the vascular ring) may require surgical treatment for the relief of tracheal and oesophageal obstruction Congenital aortic valve stenosis provides occasions for surgical relief, blind operations for this condition are being replaced by deliberate procedures under direct vision with the help of extra-corporeal circulation or hypothermia The closure of ventricular septal defects requires extra-corporeal circulation

Ductus arteriosus

This persistent channel between the aorta and the pulmonary artery, which usually closes soon after birth (1–3 months) is unassociated with cyanosis until a late stage when and if a reversed shunt develops It is a typical left-to-right arterio-venous shunt and usually the only defect present. In my own series of 186 operations associated defects have been atrial septal defects (3), ventricular septal defect (1), pericardial defect (1), congenital mitral stenosis* (1) and adult type of coarctation (2) In the infantile type of coarctation the ductus is usually open so that de-oxygenated blood passes from the pulmonary artery into the aorta to produce cyanosis in the lower limbs Its persistence in cyanotic disease such as the tetralogy of Fallot is a compensatory mechanism but unfortunately some months after birth in such patients it usually closes spontaneously

As the result of the full investigation of patients with cyanosis an increasing number of reversed shunts through a persistent ductus are being detected Although this occurs most commonly in the age group of 20 to 40 years, we have seen examples at younger ages Cardiac catheterization findings in these patients show that from time to time and under different conditions of activity the flow may be alternately from the aorta to the pulmonary artery and from the pulmonary artery to the aorta, and much probably depends on the degree of hypertension in the lungs and the state of the left ventricle In infants and young children transient reversal is not an absolute contra-indication to surgery If, however, the pressure is as high in the pulmonary artery as in the aorta permanent occlusion of the ductus may lead to right ventricular failure on the table In this type of case pressures must always be taken at operation in both vessels before and after temporary clamping of the ductus before it is finally divided

Persistent ductus accompanies some examples of coarctation of the aorta The aortic

* In one patient of five (Parsons and d'Abreu) a patent ductus arteriosus was present in conjunction with a congenital mitral stenosis associated with gross pulmonary hypertension The pre-operative angiocardiographic and catheterization studies proved that blood was flowing from the pulmonary artery to the aorta At operation the ductus was temporarily occluded and a needle connected to a water manometer showed that the pressure in the pulmonary artery rose rapidly The ductus therefore was not tied but the mitral valve was explored through the usual atrial approach and a tight mitral stenosis detected and split by the digital method

end of the ductus lies distal to the origin of the left subclavian artery and the pulmonary orifice is a little to the left of the bifurcation of the main pulmonary trunk.

The biological explanation of ductal closure or of persistent patency remains obscure With the expansion of the lungs after birth the blood flow previously diverted from the pulmonary artery to the aorta is required for lung function and is associated with a marked change in the pressure of the right and left side of the heart The foetal pressure in the right side of the heart exceeds that of the left and the reverse holds good immediately the lungs are inflated after birth The wall of the ductus is surrounded by a mass of muscle tissue which contracts though the activating stimulus is not known. It is also suggested that the sudden increase in pressure in the aorta forces a fold of tissue across the aortic mouth of the ductus If the lung is slow to expand these features may all act more slowly and the ductus as a result may remain open. Inadequate oxygenation of the blood at birth may be an important factor in persistent patency (McKeown)

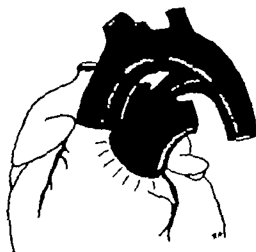


FIG 16·1 —Diagram of persistent patency of the ductus arteriosus.

Pathological anatomy

The duct may be long and narrow or so broad and short as to be stomal Its diameter is usually greatest at its aortic end The greater pressure of the aorta forces blood into the pulmonary artery which becomes dilated and the pulmonary arteries themselves are often greatly widened both changes may be well seen on radiological screening or on the plain radiograph, but it is important to remember there is no ' typical ' X ray appearance The left ventricle tends to hypertrophy and dilate and *infective bacterial* endocarditis is a complication the exact figures of which it is not possible to state The high incidence in Maude Abbott s series is partly explained by the material being gathered from autopsy findings From a surgical point of view far graver is the risk inherent in all types of arterio-venous fistula and most of these patients untreated die from heart failure though odd cases undoubtedly survive to advanced old age The average age of survival in Maude Abbott s fatal cases was 24 years The effect of the shunt is to increase the work of both ventricles and to cause pulmonary hypertension

The pulmonary artery under the constant high impact of the aortic stream may become truly aneurysmal and rupture if it has been infected mycotic aneurysms of branches of the pulmonary artery may develop if the artery wall has been infected in the *course of* infective arteritis, or as the result of septic emboli

Clinical features and diagnosis

(*a*) The *murmur* and *thrill* Characteristically a thrill is palpable in the second left interspace below the clavicle and in this the pulmonary area there is usually audible the typical machinery murmur of Gibson *it is loud* low pitched and harsh and is heard both in systole and diastole though more marked in the former and is most intense in late systole and early diastole The systolic element of the murmur is widely transmitted over the front and back of the chest and to the axilla The presence of this murmur may not be detectable in early infancy but becomes accentuated with growth it may develop quite

abruptly (Taussig) and the murmur in early years may be classified as "systolic" a be considered to be a "functional" one Pulsation is often obvious in the neck and t pulmonary element of the normally split second sound at the base of the heart is accentuat

Quite exceptionally the murmur is entirely systolic if the diagnosis is made with su a murmur it is our practice always to carry out physiological studies by cardiac catheteri *tion for confirmation* In the presence of a true Gibson machinery murmur cardiac cathet ization is not required for diagnosis

(*b*) *The size of the heart* This will depend on the size of the shunt Occasionally t enlargement may be gross often it is slight and when the ductus is small, absent



FIG 16 2 —Radiograph of a child of 7 years with a large patent ductus arteriosus

The appearances represent an extreme degree of the condition with a large pulmonary artery and extremely vascular lungs with enlargement of the heart



FIG 16 3 —Radiograph of a patient of 22 years no cardiac murmur present, large heart, enl pulmonary artery and congested lung field

The diagnosis of patent ductus was established by c catheterization and a large ductus divided at operation

(*c*) *The blood pressure* The pulse pressure is usually wide with a low diastolic pressur at times hard to determine Characteristically the brachial diastolic pressure is 20–30 mr below the normal and there is usually a low or normal systolic pressure

(*d*) *The radiological appearances* Typically there is dilatation of the pulmonary arter but this may be equally or more prominent in patients with atrial septal defect , bot ventricles may be slightly enlarged and radiological screening shows increased hilar danc which again, however, is best seen in examples of atrial septal defect The left atrium usually enlarged

Characteristically the pulmonary artery shadows in the lung parenchyma are increase (Fig 16 2) It is important to remember that characteristic radiological appearances ar not invariably present and the enlargement of the pulmonary artery may not be marke

If angiocardiographs are done (and this is rarely necessary) a bulge in the aortic shado at the site of the aortic infiltration of the ductus may be seen in the left oblique positior

(e) *The electrocardiograph* The electrocardiograph usually shows slight left axis deviation. If there is a real right axis deviation an uncomplicated patent ductus can be excluded and pulmonary hypertension is indicated. These findings are modified by the onset of heart failure when T wave inversion may be an important feature

Angiocardiography In the typical case in children and adults there is no need to employ direct visualization methods It is in infants that these methods can help the problem arises in the acyanotic child with cardiac enlargement signs and symptoms of pulmonary hypertension hypertrophy of the left ventricle on the electrocardiographic findings and with a systolic murmur Such a picture can be produced by septal defects Since the need to close a large ductus in an infant with the features mentioned above is essential pre-operative certainty in diagnosis is required and this may be made by angiocardiography or by retrograde aortography the former may show a typical infundibulum on the aortic end of the ductus while the latter will usually demonstrate simultaneous filling of the aorta and the pulmonary artery Cine-angiocardiography makes the demonstration more effective (Chapter 14) and is of great value in infants.

Physiological studies

In 95 per cent of cases the diagnosis can be made readily because of the characteristic murmur of Gibson it is in doubtful examples that cardiac catheterization is essential In such patients the signs and symptoms of pulmonary hypertension with cardiac enlargement may be associated with a systolic murmur only or with no murmur since the quality of the murmur depends on the gradient in pressure between the systemic and pulmonary circulation This is liable to happen in infants with a large ductus and patients at other ages when the increasing pulmonary hypertension is causing a right ventricular pressure that equals or approximates to that in the left ventricle such patients may show intermittent or persistent cyanosis Cardiac catheterization may prove the presence of a ductus most readily if it can be passed directly from the pulmonary artery into the aorta This is not always possible and then the pressure readings and the oxygen content findings in the blood at different levels will establish the diagnosis A high pulmonary artery pressure combined with an elevation of the oxygen content of the pulmonary arterial blood compared with that of the right ventricle would be diagnostic

Differential diagnosis

If the typical murmur is audible and the radiological appearances include an enlarged pulmonary artery and increased lung vascularity the diagnosis is made easily The differential diagnosis includes the maladie de Roger (ventricular septal defect) atrial septal defect and aorto pulmonary septal defect or perforation of an aortic sinus into the pulmonary artery

Apart from the last mentioned, which may be difficult to diagnose except at operation in the classical type of septal defect the diagnosis can be made on clinical grounds except in infants or older patients in whom heart failure and reversal of shunt have occurred. The problem is put simply by Taussig ' The diagnosis of ductus arteriosus on the basis of a murmur limited to systole is rash Fortunately in the presence of any doubt the problem can usually be solved by cardiac catheter studies and by angio-cardiography

Treatment of ductus arteriosus

Whether the ductus can be so smoothly ligated as to prevent sub-acute bacterial endocarditis remains to be determined If this is possible and operative risk can be reduced

to a minimum, the time may come when every patient with an isolated patent ductus arteriosus should receive the benefit of surgical ligation" (Taussig, 1947) That time has indeed come and the treatment of ductus arteriosus has become surgical, an operation with such a low mortality rate (Gross 1·7 per cent in 568 patients, Potts no deaths in 347, Milnes Walker nil in 50) which treats a condition in which death on an average removes 20–25 years from a normal life expectancy has been readily accepted by cardiologists who see it as a prophylactic against congestive heart failure, of bacterial endocarditis and of pulmonary hypertension, usually when the vascular bed has undergone degenerative changes The condition of the patients after operation in childhood often causes surprise to the parents who see normal growth proceed rapidly and note the disappearance of symptoms not previously regarded with concern, such as repeated bronchitis, lassitude and dyspnoea The knowledge that the child is now cured removes parental anxiety and prevents the production of a cardiac neurosis, as until operation has been done few of them allow the child to partake in normal activities

The ideal age for surgery It is difficult to accept the age of 7 as being the ideal one In the average child, operation at 3–4 is technically simple, causes a negligible mortality (none in 60 of our patients), lessens the chance of permanent damage being done to the lung vascular bed and enables the child to start full schooling at the age of 5 without the threat of interruption of this at the age of 7 Surgery may be required in the first few months of life if cardiac enlargement and pulmonary hypertension are present It is quite certain that infants with a ductus as the only abnormality do die in the first year of life* At the other end, surgery is more hazardous over the age of 20 but if signs and symptoms such as enlarged heart and increasing pulmonary hypertension are noted in the absence of cyanosis, operation should be advised The oldest patient in my own series was a woman of 48 with congestive cardiac failure without cyanosis who made an excellent recovery

Contra-indications to surgery Cyanosis due to an associated cardiac defect such as the tetralogy or tricuspid atresia is an obvious contra-indication Operation is withheld from infants until over the age of 2 unless cardiac deterioration occurs The ductus might close spontaneously, though I have no knowledge of this happening in anyone over the age of 12 months

It seems that surgical closure in cyanosed patients with permanent reversal of flow should not succeed and the mortality rate following this procedure has been very high but the point has not been settled definitely as to whether surgery under certain conditions might not be indicated When reversal has taken place, this type of ductus is associated with pulmonary arterial hypertension but has a normal or decreased pulmonary blood flow (Ziegler, 1955) The catheter findings show a normal or decreased pulmonary capillary pressure in the presence of a high pulmonary artery pressure indicating a pre-capillary pulmonary hypertension This is quite the reverse from those cases of ductus arteriosus with a high pulmonary artery pressure without cyanosis and with a high lung blood outflow into the left atrium—such demand urgent surgery In those with reversed blood flow, the radiograph shows oligaemic lungs while the E C G shows a pure right ventricular preponderance It is difficult to escape the conclusion that in these patients permanent vascular changes are responsible for the pulmonary endarteritis at the pre-capillary level If surgery is being employed for patients with pulmonary hypertension, pressures should always be taken in the pulmonary artery and aorta before and after temporarily clamping

* Maude Abbott found in 242 autopsies on ductus arteriosus patients that 48 died in the first year of life I have operated on 14 infants, all admitted in heart failure or with severe respiratory distress Cine-angiocardiography (Dr Astley) or aortography has been of great diagnostic value



(a) (b)

FIG 16-4

(a) Radiograph of the chest of a child of 6 years.

The gross lung congestion was associated with severe symptoms, the child being in hospital on many occasions for bronchitis with dyspnoea a large ductus was present (operation.

(b) Radiograph taken 18 months after the ductus had been ligated.

The symptoms have disappeared.



(a) (b)

FIG 16-5.—Coarctation of the aorta with a ductus arteriosus in a child of 4

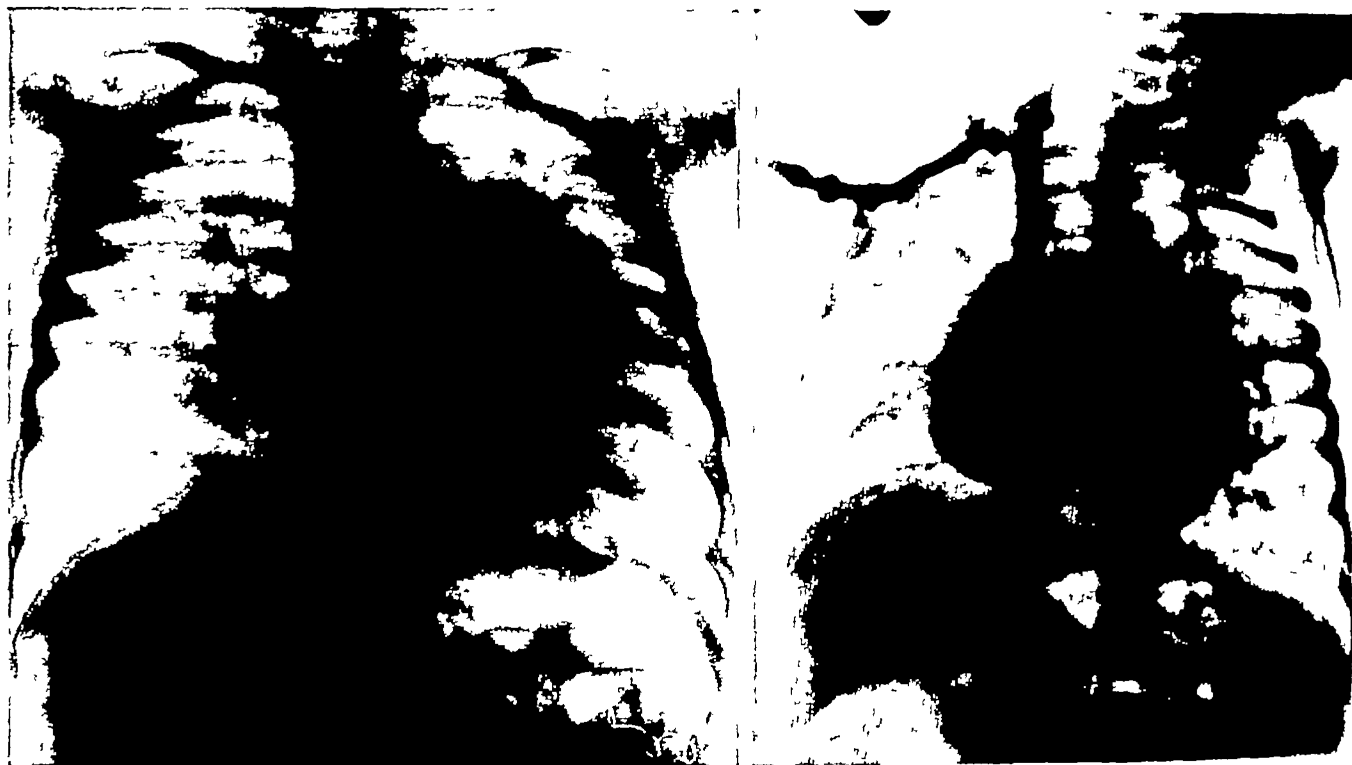
The main symptoms were pulmonary

In (a) the aorta and the ductus have been exposed and the mediastinal pleura has been retracted forward tapes have been placed round the aorta above and below the coarctation-ductus area ; note the usual post stenotic dilatation of the aorta

(b) The ductus has been divided and the pulmonary end sutured and the aorta anastomosed end to end after excision of the coarcted segment

the ductus If the pulmonary pressure rises after clamping it is a warning that the right ventricle may fail and permanent occlusion might be fatal

If bacterial endocarditis is present, full attempts must be made to sterilize the infection by antibiotics (and this is almost always successful) before the ductus is closed surgically A patent ductus associated with aortic coarctation is certainly not a contra-indication; indeed the correction of both deformities is indicated as the pulmonary hypertension is often gross in these patients The combination is present in 5–10 per cent of most large series of adult type coarctation (Fig 16 5)



(a) (b)

Fig 16 6 —Patent ductus arteriosus in a child of 12 months who was extremely dyspnoeic and cyanosed when crying The pre-operative diagnosis (which was confirmed) made by Dr Clifford Parsons and Dr R Astley was that of a large patent ductus arteriosus with great dilatation of the left ventricle

(a) Radiograph showing the large size of the heart and gross pulmonary plethora

(b) Angio-cardiogram Left oblique view showing the great enlargement of the left ventricle

The surgical closure of a ductus arteriosus

Pre-operative treatment The patient should be in the ward for a few days before the operation If the operation is to be undertaken for secondary bacterial endocarditis this period will naturally be longer so that intensive antibiotic therapy can be given The pre-operative measures include a careful charting of the blood pressure, especial note being taken of the diastolic reading, a full radiological examination, a blood count and blood grouping, and the teaching of breathing exercises by the physiotherapist

The surgical approach The classical high postero-lateral thoracotomy is preferred to an anterior one made between the second and third rib with the patient supine, the postero-lateral approach made through the third or fourth intercostal space provides a wider exposure than the more limited anterior one Instead of opening the mediastinal pleura between the phrenic and vagus nerves an incision through tissue over the aorta provides a far simpler

and clearer approach to the ductus * This incision should start in the pleura overlying the origin of the subclavian artery and reach down to an inch below the ductus In the upper part of this incision, the superior intercostal vein will require ligation and division The medial flap is dissected well forward and held up by a series of fine silk sutures which are folded over a gauze mop which covers the lung such a flap carries away with it the vagus nerve and its important recurrent laryngeal branch and the ductus is rapidly exposed. The clearing of the ductus is far simpler than through the usually adopted exposure between the vagus and phrenic nerves not only is the dissection carried through a lateral plane rather than the vertical one which makes the operator dig for the ductus but the medially retracted flap also carries away the pericardial lappet which overlies the ductus and from which a troublesome ooze of pericardial fluid comes if it should be inadvertently opened. A curved forceps is gently eased through the loose areolar tissue at the back of the ductus When this forceps has been passed the dissection of loose tissue around the ductus can be safely executed so that sufficient length is available for safe division and suture (Fig 16 7)

The question of division of the ductus In the early days of ligation re-canalization of some channels with a return of a machinery murmur may have been due to an understandable caution in the degree of force applied to the actual tying of the ligature to the employment of suture material so thick (e g tape) that it failed to occlude firmly the ductus and to the use of one tie only If thread or floss silk is used and a transfixion suture placed between the two main ligatures the risk of re-canalization would seem to be unlikely In my first 72 ligations three patients re-canalized the channels were broad in all Blalock (1951) is able to state that after interruption of the ductus by his multiple suture technique in approximately 300 patients there has been only one known example of re-canalization

Such authorities however as Gross and Crafoord advocate complete division Gross always divides the ductus and Crafoord does so in a very short broad ductus Gross first elaborated this technique but many surgeons have not adopted this measure though it would be difficult to argue against its soundness and effectiveness

In my own practice I now divide the ductus in 72 consecutive operations in which the ductus was ligated a follow up revealed that three had re-opened It is fair to say that one of these was an infected case and the other two were quite exceptionally broad ones In the last patient of the ligation series serious haemorrhage followed the tying of the ligature on the aortic end of the channel and after great difficulty the ductus was clamped divided and sutured after temporary occlusion of the aorta These experiences led me to prefer Gross s method of division for simple ligation † It is not so simple an operation as ligation and should only be done by surgeons who have a clear cut plan of action before they operate

Division of the ductus The artery forceps placed behind the ductus are held in place by an assistant while a thorough dissection of the periductal tissue is made Much fibro-areolar tissue is divided little by little to leave a completely isolated ductus which steadily becomes longer as the dissection proceeds the removal of adventitious tissue proceeds equally thoroughly over the aortic and the pulmonary artery ends of the ductus The pericardial lappet which overlies the ductus is dissected free without opening it

The upper side of the ductus must be cleared scrupulously and the space between the

* I am indebted to G A Mason of Newcastle who first showed me this approach

† In the first 100 ductuses divided there have been two deaths 9 and 17 days after operation, from secondary haemorrhages due to infection This complication has been seen by other surgeons after excision of coarctation of the aorta and in other cardio-vascular surgery The organism is usually a staphylococcus

under surface of the aortic arch and the superior one of the pulmonary trunk adequately exposed. This dissection should never be hurried or skimped.

Two fine toothed Potts' ductus clamps are placed on the aortic and pulmonary ends of the channel. The division of the ductus must be made with meticulous care to leave a fringe sufficiently large on each side to accept the suture.

The suture material is fine silk (0000 or 00000) mounted on an eyeless arterial needle. A continuous suture is placed through the ductal tissue distal to each clamp; one layer will suffice though it can be started at one end and brought back to that point by a returning line of suture. (I do not use a returning suture.) Each bite of the needle is very close to the one on each side of it. It is better to do the pulmonary end first as this rarely bleeds when the clamp is removed, whereas a little smart bleeding may occur from the aortic end. When the suture of the pulmonary end has been completed the clamp is removed and a small pack of gauze, oxycel or fibrin foam is placed on the suture line at once and maintained there by steady pressure for five minutes. At the end of this procedure it is exceptional to see any bleeding.

The aortic end is dealt with similarly; here, as soon as the clamp has been removed, it is not unusual to see one or more jets of blood under pressure squirt from a suture hole. Before this becomes troublesome a pack is quickly placed on the suture line and kept firmly in place for five minutes. Occasionally an additional interrupted suture, or two, needs to be placed; but no attempt to do this should be made until firm pressure has been given an adequate trial, well beyond the limit of five minutes.

Fibrin foam, oxycel or crushed muscle can be placed on both ends before the chest is closed.

Before a reasonable experience of this operation of division has been gained it is wise to clear the aorta of adventitious tissue above and below (see Fig. 16.7(*c*)) the ductus so that a *temporary clamp or a Potts' clamp* as used for aortic-pulmonary anastomosis can be applied if significant bleeding should follow the suturing of the aortic end of the ductus.

Ligation of the ductus. If the operator prefers ligation two stout ligatures (25 thread) grasped in the tip of a pair of long artery forceps are held down to the open jaws of the curved forceps previously passed and which is now closed and withdrawn to carry the suture material around the ductus. These ligatures are firmly tied and perhaps a fine suture passed through the ductus between them and tied. A case, however, could be made for the use of a single ligature tied in the middle of the ductus. It is difficult to write about ligation with conviction as I believe division to be a much sounder surgical operation, provided the difficulties are fully realized. It is not a safe procedure in the hands of the occasional operator.

The mediastinal pleural flap is loosely sutured back in place and the lung fully re-inflated by the anaesthetist. The chest can be closed with or without drainage.

Post-operative progress

This is usually uneventful. Any sign of post-operative cyanosis calls for immediate oxygen therapy but this is rarely required. The pulse rate may be raised for 48 hours but then subsides; in older patients tachycardia may be very evident. The diastolic pressure will have risen to a normal figure. In our series, effusions have not been a problem and normally no aspiration has been needed. As a routine, a radiograph is taken by the portable machine on the day after operation to exclude or confirm the presence of atelectasis or of post-operative effusions. The patients are usually up on the fourth or fifth day.

They should not return to full activity for four weeks but after that a sensible return to a normal life free from restrictions is encouraged

Special considerations in infected patent ductus

By the thorough use of parenteral antibiotics bacterial endocarditis which involves chiefly the pulmonary artery can be sterilized It is important to remember that surgery before the era of penicillin was able to provide a cure (Tubbs and Keele 1940) It is therefore clear that after parenteral antibiotic therapy has cured the infection operation

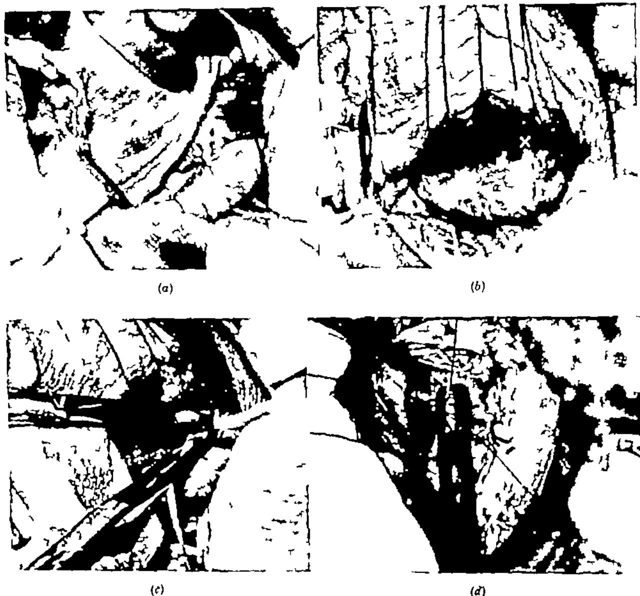


Fig 16·7 —Division of ductus

(a) The lung is being held down and forwards over a moist pad the start of the descending aorta is well exposed.
(b) The mediastinal pleura over the aorta has been incised vertically its medial flap is held medially by retracting sutures which carry the vagus nerve and at the same time keep the lung away from the ductus area which can be seen marked X.
(c) The ductus has been divided between Potts ductus clamps ready for sutures to be placed.
(d) The aortic end suture is completed. The pulmonary end has been closed and its clamp removed

should be practised to avoid the risk of recurrence of the illness Quite exceptionally an infection may arise that will prove to be insensitive to any known antibiotic and then immediate ligation or division will be required to save life

A superimposed infection causes symptoms at first less marked than those of bacterial

endocarditis in valvular disease, whether acquired or congenital Malaise, early fatigue, irritability, anorexia, fever with rigors and cough may be present but sometimes the only feature is an unexplained pyrexia associated with a typical Gibson murmur Distant emboli may cause haemoptysis, petechiae and blood cells in the urine The blood culture is not always positive as the dislodged bacterial emboli may not pass beyond the lung parenchyma Pulmonary emboli may be an early cause of haemoptysis, which may also follow the development of mycotic aneurysms in the pulmonary arterial system Areas of lung infarction may be detected on the radiograph Although the endocarditis spreads well beyond the ductus its ligation checks the process and the blood culture becomes negative

A full course of systemic penicillin should be given and this will often lead to great clinical improvement, the blood culture becoming negative.

The operative closure of the ductus is difficult in these patients if there is inflammatory matting of the periductal tissue and the isolation of the duct should not be attempted until the aorta has been cleared of adventitious tissue above and below the ductus to such a degree that temporary clamps can be applied rapidly should accidental tearing of the ductus follow, as the wall of the pulmonary artery may be friable as the result of the arteritis The ductus itself may become the site of a fusiform or saccular aneurysm

Operation for re-canalized ductus

Increasing numbers of re-canalization are being reported following simple ductal ligation, most of these are after operations for a short wide ductus or in patients in whom the ductus before the first operation had been the site of the infective arteritis Another complication is the development of an aneurysm at the site of the ligated ductus



FIG 16 8 —An aortico-pulmonary fistula

Through a trans-sternal transpericardial approach, the fistula has been divided and the pulmonary and aortic ends sutured

Re-operation is a formidable undertaking Before any attempt is made to explore the ductus, the aorta above and below it must be fully mobilized and cleared, so that temporary clamping by two Potts' clamps or by a large Potts' aortic clamp (see Fig 17 3) can be easily applied in the event of haemorrhage Similarly the pericardium should be opened and the pulmonary artery thoroughly explored so that full access is available for a lateral clamp of the Satinsky type to be applied to that artery in the case of haemorrhage

Aortico-pulmonary fistula

In this congenital defect, symptoms depend on the size of the left to right shunt When this is large, severe pulmonary hypertension will arise and shunt reversal will

differential cyanosis may develop Usually before this occurs the condition will have been suspected quite often to be a ductus arteriosus producing a forcible heart action a collapsing type of pulse a systolic murmur or a machinery murmur A cardiac catheter might pass into the aorta The condition may first be diagnosed at thoracotomy for a supposed ductus the thrill will then be felt at the site of the fistula The fistula is divided between Potts clamps and the ends oversewn as in the division of a ductus As this deformity occasionally complicates a transposition of the great vessels, a full study of the base of the heart must be made before the fistula is clamped as such a manœuvre will obliterate a main junction between the two systems and lead to death Bailey (1955) in his book discusses fully this condition which was first treated surgically with success by Gross The operation is much facilitated by a transverse division of the sternum (see Fig 16 8)

Coarctation of the aorta

Stenotic and atretic lesions of the aortic arch are surprisingly common (Brown 1939 1950) and provide many different varieties some not compatible with life In distinction to other acyanotic lesions they are commoner in boys than girls The surgical interest in aortic stenosis devolves largely on coarctation seen near the area where the ductus arteriosus leaves the great vessel (the adult type) the infantile coarctation (Bonnet 1903) is a diffuse narrowing of the aortic isthmus often associated with hypoplasia of the arch and a large ductus arteriosus through which blood may pass from the right ventricle to the abdomen and lower limbs which in consequence will be cyanosed In most examples of coarctation of the aorta in adults the narrowed or obliterated segment is distal to the origin of the left subclavian artery It is not really possible to separate infantile from adult coarctation as both conditions can be merged one into the other rarely, the stenotic area may lie between the left carotid and the left subclavian arteries The important differentiation is when there is a persistent ductus if the ductus is inserted above the coarctation the shunt is left to right and the operation is necessary to correct pulmonary hypertension If the ductus is below the stenosed segment blood flows from pulmonary artery to aorta, causing cyanosis of the lower limbs

Most exceptionally atresia may be present in the thoracic or abdominal aorta * the ductus arteriosus may be patent as an associated defect (10 per cent) and the aortic valve may have only two cusps (22 per cent of cases) (Abbott 1936) The aorta is usually dilated and thinner beyond the coarcted area (post-stenotic dilatation) the area of stenosis may be sclerotic or calcified and vegetations of the type seen in endocarditis may develop Great dilation of the aortic intercostal vessels below the atresia enables a reasonable collateral circulation to be achieved for the body below the obstruction These vessels are tortuous and where they communicate with the arteries of the back they form large channels which erode the ribs and give the *characteristic notching* and sclerosis of the lower edges of the ribs These abnormally large tortuous vessels may be felt over the upper part of the body especially in the scapular area and in the intercostal spaces Where these dilated vessels enter the aorta aneurysms may arise even at an early age Intra-cranial aneurysms are present in 5 per cent of patients

Inside the narrowed area of the coarctation is a diaphragm which usually has a tiny

* In these cases the aorta is usually the seat of a long stretch of hypoplasia In one patient an aortic graft was used the systolic blood pressure fell from 220 to 140

opening in its centre, often smaller than a pin-head, both above and below this area is an area of fibrosis with no evidence of an arterial media In addition to this lack of a true middle coat is a firm adherence of the stenosed area to the surrounding tissue from which at operation it has to be freed by sharp dissection especially in the area close to the obliterated or open ductus arteriosus



FIG 16 9—Excised segment of coarcted aorta seen from below

Note the small crescentic slit in the diaphragm of the intima Resected from a girl of 7 years with a pre operative blood pressure of 190/120 6 months after aortic anastomosis the pressure was 120/80

The clinical features. The extent and size of complicating side effects such as hypertension and cardiac enlargement govern the presence or absence of symptoms Many young patients are now being diagnosed because of a full cardio-vascular examination after a basal systolic murmur has been heard in a routine inspection and since scepticism has arisen about the diagnosis of functional systolic murmurs If hypertension or cardiac failure have developed, severe symptoms of headache, dyspnoea, cardiac pain and exertional fatigue may follow In the symptomless group, the diagnosis is easily made if the routine of examining the femoral pulses and taking the blood pressures in both upper and lower limbs is followed, as differences in these two areas are the characteristic feature

"Coarctation of the aorta still passes unrecognized—it will continue to be missed if a striking collateral circulation is always expected to be self-evident It will be diagnosed if the femoral pulse is felt for and the blood pressure taken in the legs in every case with high blood pressure or with basal systolic or diastolic murmurs, or with wide pulsation in the neck when these are without an obvious cause" (Campbell and Suzman, 1947–48)

The blood pressure in the upper limbs, head and neck is usually raised to a degree of hypertension (150–320 systolic) with a low blood pressure in the lower extremities and the heart will be enlarged, often with electrocardiographic evidence of left ventricular hypertrophy Claudication on exercise may affect cold, numb legs

These clinical features, together with a systolic thrill and murmur over the base of the heart and the detection by sight and palpation of the prominent heart and collateral vessels on the chest wall, especially in the region of the scapula and the antero-lateral part of the chest, make the diagnosis certain Further confirmation comes from a typical radiological appearance of "rib notching" and obvious scleroses on the inferior surfaces of the posterior portions of the ribs The notching is not present in the very young or when there is a patent ductus arteriosus (Evans, 1933). The aortic knuckle shadow is absent on the radiograph and the left subclavian artery is much enlarged. On screening the findings depend on the age of the patient and the course of the condition, there may be gross hypertrophy and dilatation with vigorous pulsation usually of the ascending aorta

Prognosis This is perplexing and only its full evaluation can decide the ultimate place of surgical excision Undoubtedly some patients lead a normal life until middle age, but many die at about 30 years of age

Perhaps the profession is mesmerized into optimism by the undoubted survival of a few remarkable and exceptional subjects to the age of 60 or 70, but Crighton Bramwell at

the International Conference of Physicians London September 1947 reported 13 patients first seen when over 30 and all of them lived to over 50 He suggested that the third decade was the dangerous period and the prognosis is fair if they survive this age In another series (Reifenstein, Levine Gross 1947) 61 per cent out of 104 patients died before the age of 40 Blackford (1928) found in a large series (323) that 40 per cent died between the ages of 16 and 30

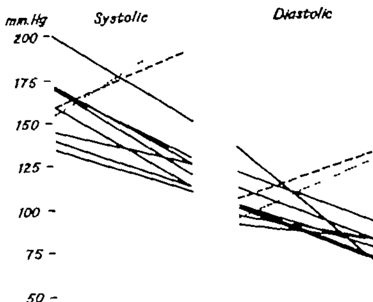


Fig 16-10 —Blood pressures in ten children before and after operation for coarctation of aorta. See text for reasons of the two failures to lower the blood pressure

The cause of the hypertension The most probable explanation of the rising blood pressure is that it represents the increased peripheral resistance to blood flow this might be accompanied by a peripheral arteriolar resistance brought on by the results of renal ischaemia That the mechanical obstruction is the real cause is proved by the uniform fall in blood pressure if a good calibre aortic passage is established by surgery In support of the theory of renal ischaemia could be cited the fact that the full effect of the fall in blood pressure is not complete sometimes till three weeks or longer after surgery

Parsons (1950) investigated ten children whose coarctations I resected followed by anastomosis In eight of these blood pressures came down in the arms with equalized or slightly higher blood pressures in the lower limbs In two one an infant and one a boy of 10 the blood pressure continued to rise in both of these we now have certain proof that the site of anastomosis is narrow One of these a boy of 16 has been re-operated and an aortic graft inserted with fall of blood pressure Table (Fig 16 10) reports the blood pressures at time of admission and at discharge of these ten patients

Cleland (19 0) in reviewing forty operations for coarctation found that in all the patients the brachial blood pressure was lowered

The deaths are due to heart failure hypertensive failure which may include cerebral haemorrhage rupture of the aorta with or without associated saccular or dissecting aneurysm (Fig 16 12) or of aneurysmal dilatation of vessels as all the vessels taking part in the vast collateral circulation are subject to this I have seen coronary thrombosis as the cause of death in a boy of 14 Another hazard is that of infective endocarditis which may effect abnormal aortic cusps or the coarctation itself

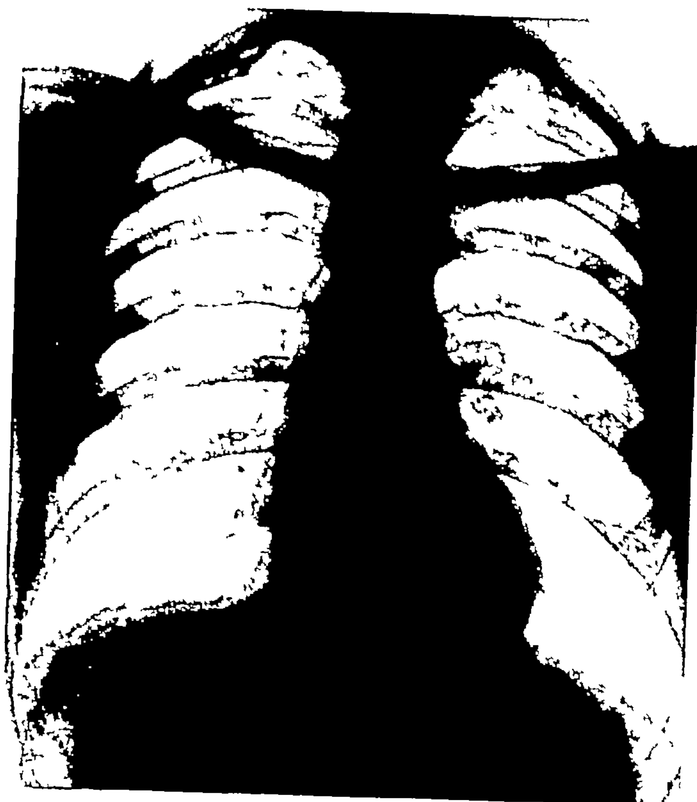


Fig 16 11



Fig 16 12

Fig 16 11 —Radiograph of a patient of 17 years with a coarctation of the aorta In spite of a blood pressure of 210/140 the heart was not enlarged There is a characteristic absence of the aortic knuckle and notching of the ribs At operation when the coarcted area was successfully resected small aneurysmal dilatations were present where the intercostal vessels joined the aorta below the stenosis

Fig 16 12 —Radiograph of a patient of 42 who six months before collapsed at work after a sudden severe pain in the upper left chest and epigastrium This had been preceded by exertional dyspnoea for several months Clinically there was obvious cardiac enlargement with a systolic murmur audible in all areas The blood pressure was 250/140 in the right arm and 185/165 in the left arm there were no palpable femoral pulses enlarged pulsating vessels were felt over the chest wall In addition to the aneurysm seen on the radiograph notching of the ribs is obvious on the right side The patient died suddenly a year after this radiograph was taken

The indications for surgery. Opinion in the last five years has become more and more insistent on operation in patients between the ages of 6 and 20 If the patient is first diagnosed over this age, surgery is not always advised if there are no symptoms, as the mortality rate at older ages is higher than in the younger group If, however, symptoms and cardio-vascular deterioration are progressive, operation should often be advised in view of the grave prognosis The mortality rate including all age groups is below 10 per cent and is steadily dropping in all centres There can be no doubt that in patients between the ages of 5 and 15 years the mortality rate is lower and the results good My own preference is to operate in all cases diagnosed in childhood about the age of 8 It is the acceptance of the bad risk cases that is the main cause of the surgical deaths Operation may be necessary in infants who show signs of heart failure and an enlarging heart Such infants usually reach hospital in heart failure the diagnosis is made on finding a large heart with a forcible apex beat and a systolic murmur at the base of the heart The oblique radiograph shows a large left ventricle The femoral pulse is absent or diminished As the condition is often associated with a ventricular septal defect angio-cardiography is often done , retrograde aortography is of great value in delineating the exact anatomy (Fig 14 3) If in spite of adequate medical treatment the infant's condition deteriorates, surgical excision, which is technically easy in these infants, is employed The anastomosis must

be made with interrupted sutures to allow the lumen of the anastomosed area to grow with advancing age If they respond well to medical treatment surgery is delayed

The surgical procedures Excision of the stenosed segment followed by end to-end anastomosis (Crafoord Gross) is undoubtedly superior to the operation of anastomosing the left subclavian artery after its division to the lower aortic segment (Blalock)* but the latter operation still has a small place it is helpful for those patients with a long segment of stenosis which after excision left the two aortic ends so widely separated that suture of them was impossible In such a situation Gross (1949) has perhaps solved this problem by initiating the use of preserved human aortic grafts

Many observations have been made on the results of subclavian aortic anastomosis and without exception they indicate its inferiority as measured by the test of adequate raising of the blood pressure in the lower limbs for this is usually rather disappointing In one of our patients after an end to-end anastomosis had been performed in a boy of 9 a longitudinal tear developed in the lower aortic segment requiring ligation of the aorta as this developed after a five hour operation and the general condition was poor the chest was closed the operation had been done because of severe headache with a hypertension of 190 mm Hg (systolic) In the course of the next few weeks the boy deteriorated head ache and vomiting became continuous and the systolic pressure rose to over 210 The subclavian artery was then anastomosed by end to-end suture to the lower aortic segment and five years later he is in excellent health with a blood pressure of 120/80 and symptom free the pressure in the femoral artery is only 10 mm mercury less than that in the arms The subclavian artery was of the same diameter as that of the aorta below the site of the coarctation. This operation however should not be employed as the procedure of choice

The operation of excision of the coarctation and end-to-end aortic anastomosis A wide posterolateral thoracotomy is made with the patient in the lateral position lying on the right side the exposure itself is a formidable procedure because of the large arterial channels that exist in the skin and muscles in the line of the incision in the presence of a high blood pressure The incision should be made in small sections at a time and blood transfusion is started at once The whole length of the fifth rib is excised

The mediastinal pleura over the aortic arch the area of the coarctation and for at least three inches over the thoracic aorta is divided The coarctation site may show a very obvious coarctation or be the site of a thick mass easily palpable The aorta below the coarctation is thin without pulsation and a thrill may be palpable The great size of the vessels above the coarctation is obvious the internal mammary artery being the size of a normal axillary artery The intercostal arteries are all grossly enlarged thin walled and tortuous as already mentioned they may show aneurysmal dilatation at the point of entry into the aorta

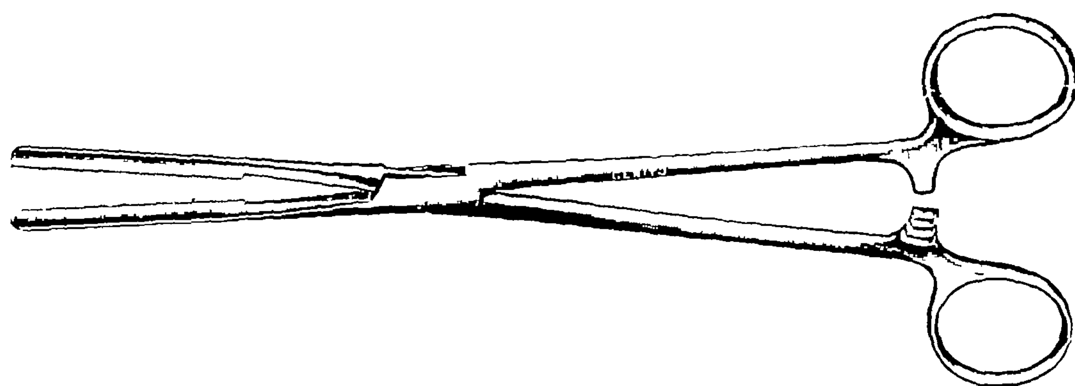
The isolation and division of the upper intercostal arteries below the coarctation is one of the most difficult and tedious parts of this exacting operation no more should be sacrificed than is essential to allow the aorta to be fully mobilized. Crafoord frequently does the operation without sacrifice of any using *temporary bulldog* clamps on them after

* It is important to quote Blalock accurately : he reserves subclavian aortic anastomosis for the infantile type of coarctation that is long or the adult type when the proximal or distal segment is hypo plastic for a short distance The whole of the constricted segment is excised and the proximal end of the aorta closed by suture : the subclavian artery is rotated down in such a way that it is not kinked and is anastomosed to the distal end of the aorta In three children treated by this method we have had good results in two and a poor result in one

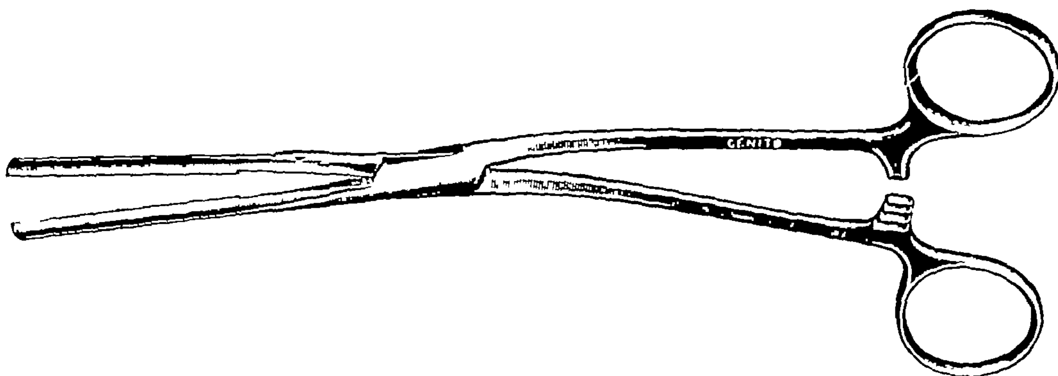
their meticulous isolation, but division of two or three pairs is of little account if a good anastomosis is obtained The adventitia of these and of the bronchial arteries which lie on the medial side should be opened freely before the vessels are encircled and ligated their thinness makes them very liable to rupture They should be tied with silk or linen thread.

The aorta is then held up in linen tape to enable the vessel and the constricted area to be elevated and completely freed of surrounding attachment the mobilization of the atretic segment may be difficult in the region of the obliterated ductus arteriosus which is divided between ligatures It may be patent (Fig 16 8)

The left subclavian artery and the aorta between it and the left carotid artery are mobilized with advantage except in patients where there is plenty of room for the application



(*a*)



(*b*)

Fig 16 13

(*a*) Potts' straight stainless steel coarctation clamp
(*b*) Potts' angled stainless steel coarctation clamp
(G U Mfg Co)

of an aortic clamp well above the coarctation If the mobilizations mentioned are executed clamps can be placed across the aorta and the subclavian artery if the segment below the last-named artery is very short Whenever possible, however, occlusion of the subclavian artery should be avoided, as its temporary obstruction greatly adds to the burden of the heart beating against an already high peripheral resistance

When the aorta has been mobilized, the aortic clamps are placed above and below the coarcted segment the best clamps are those devised by Potts of Chicago (Fig 16 13) These should be placed vertically with the handles up towards the ceiling this position of the clamps means that there will be no difficult back wall requiring anastomosis The clamps can be easily and smoothly approximated by means of the vice devised by Brom When the coarcted segment has been excised sufficiently to produce an upper and lower

segment of sufficient calibre (the upper end should be cut obliquely as the calibre of that segment is usually narrower than that of the lower one) the clamps are approximated by screwing up the Brom instrument

The anastomosis is then made by a continuous everting mattress suture of 0000 silk interrupted at both ends (Fig 16.14) In children the sutures should be interrupted everting

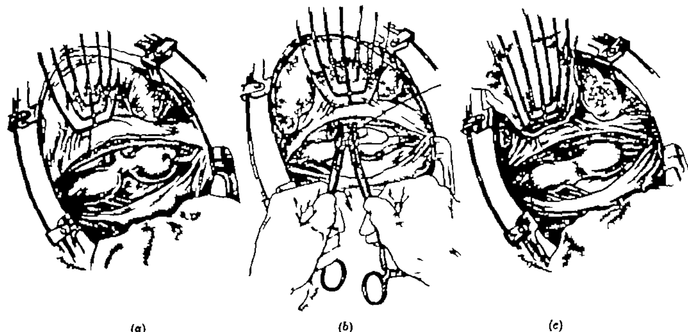


FIG 16·14 —The operation for coarctation.

(a) The coarctation has been exposed
(b) The ligamentum arteriosum has been divided The coarctation excised after the aorta has been clamped above and below
(c) End to-end aortic anastomosis completed.

mattress ones as such a technique allows the sutured area to enlarge with natural growth Fig 16 14 indicates some of the details of the operation Great advantages however can be obtained by placing the Potts coarctation clamps (which I now always use) vertically on the aorta above and below the coarcted segment so that the handles point up to the ceiling this abolishes a back wall to the anastomosis and the sutures can be placed laterally which is much easier technically

There is much to commend the use of hypotensive anaesthesia during part of the operation for coarctation this not only reduces the blood loss but renders the upper aortic segment relatively flaccid and makes the isolation and securing of intercostal vessels a good deal safer Our practice is to use Arfonad as a routine at certain phases of the operation

The lower clamp is removed first it is usually accompanied by a slight leak of blood as the pressure within the lumen is not sufficient to tighten up the suture line if bleeding is excessive at any spot an interrupted mattress suture is applied as the upper clamp is slowly removed the anastomosed segment fills with blood and the previous oozing ceases Gross (1947) advises that the upper clamp should be released very slowly (five minutes) so that there is no sudden release of blood into the lower part of the body leaving sufficient blood pressure in the left ventricle to supply the coronary artery at the moment of release the blood drip rate should be rapidly increased and the head of the table lowered as soon as the lower clamp has been released pressure over gauze pledglets should be maintained for five minutes The chest is closed in the usual way with temporary intercostal water-sealed drainage

The use of grafts, human or plastic At times the use of preserved human arterial grafts or of ones made of synthetics such as Orlon mesh is essential It is clear that all surgeons wish to avoid using dead material for replacement of such an important vessel as the aorta as the future fate of such anastomoses is problematical and calcification has already been noted If, however, the segment of coarcted aorta is so long that a good calibre anastomosis cannot be obtained by end-to-end suture this method is necessary Grafting is necessary sometimes if aneurysm of the aorta, a persistent ductus or aneurysms of the upper intercostal vessels make resection and adequate anastomosis impossible Sellors (1956) has illustrated the type of problem presented by such aneurysms and the need for aortic replacement by grafts in such a situation At the moment of writing, I use human aortic grafts prepared by the dry freezing method and am grateful to my colleague, A J H Rains, who supplies these from the arterial bank in the Department of Surgery A practical point in the use of human grafts is that after the graft has been reconstituted to normal appearances by warming, the areas in the graft which mark the egress of intercostal arteries should be closed by small sutures (00000 silk) as reliance cannot be placed upon simple ligation of these

No operation on coarctation should be carried out unless a graft is available

A clear discussion on the subject of grafts is available (*Cardio-vascular Surgery*, 1955)

Abnormalities of the aortic arch and their significance in thoracic surgery

Abnormalities of the aortic arch may be of surgical significance, only the briefest reference can be given here The abnormalities are due to faulty persistence of the embryological aortic arches which in early life unite to form the dorsal and ventral aortae Some of these arches persist in life, e g the third forms the internal carotid artery, the fourth right one persists in part as the innominate and subclavian arteries, that on the left providing part of the aortic arch, the sixth arch providing the pulmonary artery and on the left the ductus arteriosus The remainder of the arches disappear but may show irregular persistence and produce the most bizarre aortic arrangements and many odd combinations have been noted The aorta may be right-sided at first and then pass over to the left side behind the trachea and the oesophagus Persistence of the left part of the aortic system may coexist so that a vascular ring encircling the oesophagus and trachea may be present This ring or the abnormal retro-oesophageal course of a left subclavian artery arising from the right of the aortic arch may cause dysphagia, and in a few recorded examples relief has followed surgical division of certain components of the ring

Dysphagia is rare but usually arises only in the presence of degenerative enlargement of the abnormal vessels in the later years of life The abnormality may also cause dyspnoea from tracheal encirclement and Gross (1945) first relieved this by surgical division of the vascular ring It is important to remember that in performing the operation of Blalock for congenital cyanotic lesions difficulty may be encountered in finding and exposing the subclavian artery if it is in the retro-oesophageal position These conditions can be diagnosed radiologically

In perhaps 25 per cent of congenital lesions of the tetralogy of Fallot type the aorta may descend on the right side This can be readily demonstrated on radiological screening especially when the oesophagus is outlined by barium (Bedford and Parkinson, 1936) To the surgeon this is important when he is deciding upon the approach to be adopted for Blalock's operation and the pre-operative evaluation of which systemic artery will be available for the anastomosis.

Gross and Ware (1940) classify aortic arch anomalies as follows

(1) *Right aortic arch*

(*a*) Situs inversus viscerum (*b*) Right aortic arch without inversion

(i) Anterior type with the arch anterior to the trachea and the descending aorta right-sided

(ii) Posterior type—the arch passes to the left behind the oesophagus and the aorta descends to the right of the normal left-sided position

(*c*) Right aortic arch in which the left subclavian artery arises last from the arch and crosses behind the oesophagus (*d*) Right aortic arch with no vessel arising from the arch, crosses the mid line behind the oesophagus (*e*) Right aortic arch with a persistent left aortic diverticulum giving origin to the left subclavian artery and the ligamentum arteriosum

(2) *Double aortic arch*

(*a*) One aortic limb patent (*b*) Both aortic limbs obliterated

(3) *Anomalous right subclavian artery* This arises from the left side of a normal aortic arch to its distribution on the right side

(4) *Patent ductus arteriosus* (5) *Coarctation of the aorta*

A right aortic arch represents a persistent right fourth branchial artery The left one normally forms the arch Many variations in the origin and course of vessels arising from a right-sided arch have been noted.

Abnormal origin of right subclavian artery

One of the commonest anomalies of the aortic arch is when the right subclavian artery arises from the left side of the arch and proceeds upwards and to the right behind the oesophagus or between the oesophagus and trachea Holzapfel (1899) found the artery behind the oesophagus in 107 cases between the oesophagus and trachea in 6 and in front of the trachea in 6 The vessel usually crosses the mid line of the body at the level of the third dorsal vertebra Often there is a slight aneurysmal dilatation of the subclavian as it leaves the arch In 1794 Bayford reported his case of dysphagia lusoria in a woman who had suffered from dysphagia for years At post mortem examination the oesophagus was seen to be indented by an abnormal right subclavian artery but the abnormality may exist without causing any symptoms Gross in 1946 knew of six cases demonstrated radiologically In four of the children there was no dysphagia slight dysphagia that remitted in one and in the sixth (a four month infant) the dysphagia was so severe that the artery had to be divided If the vessel passes in front of the trachea there are usually no symptoms Fortunately division of the first part of a subclavian artery is not likely to impair the blood supply to the right arm There was no real stridor in Gross s operation case

Of the recorded vascular rings many have been seen in adults with no symptoms they may cause mild or severe dysphagia later in life when atheroma has caused enlargement of the vessels but in infants serious obstruction and early death has been noted (Gross 1945)

Vascular rings in the mediastinum (double aortic arch)

Gross (1945) was the first surgeon to apply the anatomical knowledge of aortic anomalies to the relief of patients suffering from dyspnoea or dysphagia or both

(A) The main aortic arch may pass behind the oesophagus instead of in front of the trachea The pulmonary artery is anchored to the distal arch by the patent ductus arteriosus or the ligamentum arteriosum to the left of the oesophagus and trachea

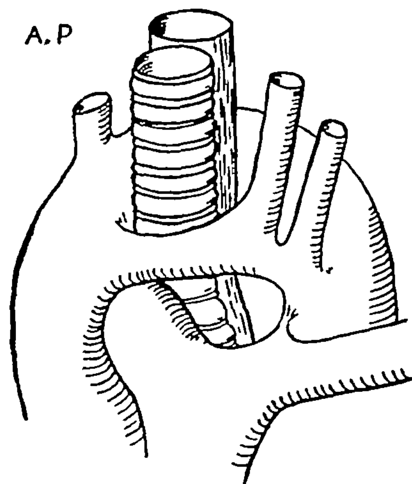


Fig 16 15 —Diagram of double aortic arch (after Gross)

If such a combination produces obstructive symptoms Gross thinks that division of the ductus might relieve them

(B) *Divided or split aortic arch* In this abnormality the aorta has two limbs, one passing to the left behind the oesophagus with the other proceeding to the left in front of the trachea Both then join to the left of the mediastinum to form the descending aorta, the great vessels may show unusual sites of origin from either limb, and such abnormal arrangements might make division of the arch impossible

Gross's first patient This was a four-month-old infant admitted to hospital 14th October 1944, because it had wheezed since birth On radiological examination a wide superior mediastinal shadow was noted and thought to be an enlarged thymus which was treated by deep X-ray therapy without improvement A month later the infant was ill with cough, noisy breathing, vomiting and a temperature of 101° Four months later the infant was in hospital again, a hoarse cry and cough severe enough to interfere with feeding were associated with a temperature of 102° and a pneumonic infiltration which improved with chemotherapy though the middle lobe remained collapsed In May 1945 the infant, a well-developed child, was re-admitted in acute respiratory distress, cyanosed and pyrexial

A barium swallow showed slight narrowing of oesophagus opposite third and fourth thoracic vertebra and a lateral view showed posterior indentation of the oesophagus A mass was seen between the oesophagus and the vertebral column while lipiodol in the trachea disclosed a narrowing of the trachea above its bifurcation

After another respiratory crisis operation was decided upon and through a left anterior thoracotomy the great vessels were visualized

A divided aorta encircled the oesophagus and trachea The ligamentum arteriosus was divided with only slight relief As the posterior part of the arch was bigger the anterior part was divided This at once relieved the trachea and most of the stridor disappeared To further increase the peri-tracheal space Gross then lightly sutured the left common carotid artery to the back of the sternum The patient made an excellent recovery

In June 1950 we were able to relieve a child with gross stridor and cyanosis who had suffered symptoms very similar to those in Gross's patient At thoracotomy there was a double aortic arch present, fortunately the smaller part of the ring lay behind the oesophagus and this was divided with complete relief (d'Abreu, Astley, Parkes, 1952) Since then we have had further examples

Atrial septal defect

These defects provide complex embryological, diagnostic and surgical problems, some not fully solved The two chief defects are the so-called ostium primum and the ostium secundum The inter-atrial septum consists of the fusion and overlapping of the two membranes, the first of these, the septum primum, grows from above downwards to the area of the atrio-ventricular valves and the ventricular septum very early on in foetal life (fourth to sixth week) The lower central part of this septum is the last to join up with the ventricular and the tricuspid valve medial attachments and a crescentic opening (the ostium primum) is slow in being filled in While this occlusion is taking place, the upper part of the septum breaks down into what may persist as the ostium secundum if the septum

secundum a sheet which grows up from below to the right of the septum primum fails to close it off properly The two septa do not close off functionally one atrium from the other as between them there is valvular aperture the foramen ovale which allows free egress of blood from right to left until birth when this passage becomes shut down

If the atrial septal defect is largely one of a persistent ostium primum it will be obvious that surgical attempts to close this will present special difficulties These difficulties may be summarized as follows the defect at the lower border of the septum may be so complete that no atrial tissue exists above the mitral and tricuspid valves and therefore no sutures

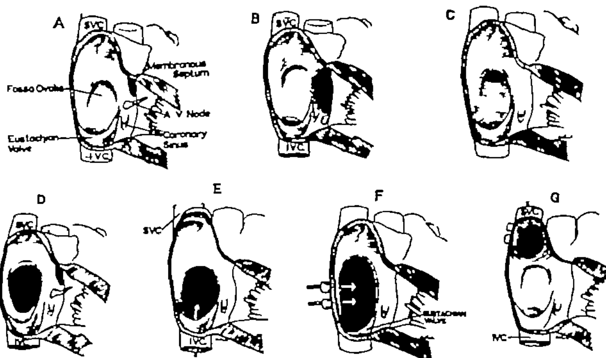


Fig 16-16—Anatomy of atrial septal defect viewed from right atrium.

(A) Normal atrial septum. (B) A V type of defect. (C) Widely patent foramen ovale. (D) Fossa-ovalis defect with complete septal rim. (E) Low fossa-ovalis defect astride inferior caval orifice with large eustachian valve. (F) Large fossa-ovalis defect without any posterior septal rim pseudo-anomalous right pulmonary veins. (G) Superior caval type of defect showing entrance of right upper pulmonary veins.

(Bedford and Sellors, *Lancet*.)

can be placed except in the origins of the valve cusp or in the top of the ventricular septum In this area runs the bundle of His and danger to this by suture may be disastrous the deficiency at the caudal end of the septum may be extensive enough to leave a defect in the original atrio-ventricular canal so that both atria and both ventricles communicate with each other (canalis atrio ventricularis communis) Such a defect can only be closed with the aid of extra-corporeal circulation

The ostium secundum defect offers a far better opportunity for closure either by closed or open cardiac surgery but here again much depends on the extent of the defect and it must not be thought that a moderately-sized defect well placed in the centre of the septum will always be present Complex defects may be encountered including complete absence of the septum a very lowly placed defect near the inferior vena caval orifice and the entry of anomalous pulmonary veins into the right atrium

Atrial septal defects may have important associated lesions developmental or acquired Mitral stenosis (usually rheumatic in origin—Lutembacher's syndrome) pulmonary valve stenosis and anomalous drainage of the pulmonary vein into the right atrium are the most important Not infrequently there is a left superior vena cava draining into the coronary sinus in closing an atrial septal defect by the open method such a vessel requires temporary

occlusion The inferior vena cava may open partly into the left atrium , I have encountered two inferior venae cavae draining into the right atrium during an operation for septal defect If pulmonary or mitral stenosis or anomalous pulmonary veins coexist then simultaneous correction may be necessary Bailey was the first surgeon to do a digital valvotomy on the stenosed mitral valve through the septal defect by a right trans-atrial approach before doing the septal defect , he indicated the need for and outlined the technique for directing the blood flow from anomalous pulmonary veins to the left atrium during the course of operations for closure of the septal defect , pulmonary valvotomy can be done at the same time as septal defect closure It is most helpful to know pre-operatively from the result of catheter and angiocardiographic studies whether the atrial defect is complicated by any of these anomalies

Clinical features. This is the commonest of all congenital heart abnormalities (J W Brown) It may be an essential defect for the maintenance of life in certain abnormalities , it is commoner in females Although some infants die when the defect is severe, symptoms do not usually arise until the late 'teens or twenties when the symptoms, followed by increasing cardiac enlargement, develop At that time the cardiac enlargement, the systolic murmur, the loud pulmonary second sound, the palpable diastolic shock in the pulmonary area and the radiological appearance of an enlarged pulmonary artery and a large right atrium are all obvious A pronounced dance in the hilar branches of the pulmonary artery supports the diagnosis Cardiac failure and atrial fibrillation may develop The electrocardiograph classically shows a right axis deviation with a right bundle branch block The picture alters when the right atrial pressure equalizes and then exceeds that in the left atrium, with development of cyanosis In the differential diagnosis from persistent ductus arteriosus if a systolic murmur only is present or from ventricular septal defect, cardiac catheterization will be of great value, showing a rise in oxygen content over that estimated from blood in the superior vena cava, if the examination is done before cyanosis has developed When a right to left shunt has developed, angiocardiography will help , the development of cyanosis in a patient with obvious pulmonary plethora is clearly an indication of a reversal of a previous left to right shunt, rather than indicating congenital cyanotic heart disease As in the case of a reversed ductus shunt producing cyanosis, surgical treatment of a reversed atrial flow is not likely to be possible The surgeon will want, if possible, to know whether the defect is an ostium primum or secundum and whether anomalous pulmonary veins exist Cardiac catheterization and careful E C G studies will provide the best information on these points

Pathological changes and their influence on prognosis. In any sizeable defect, the pulmonary arterial flow will be greatly increased with the ultimate development of pulmonary hypertension and of right-sided hypertrophy The onset of flow reversal as the atrial pressure rises is often accompanied by cardiac failure The whole pathological process is accentuated by accompanying valvular obstructions such as mitral stenosis and pulmonic stenosis These effects are reflected in the death rate from cardiac failure of many of these patients in the thirties, though undoubtedly long survival has occurred in a few individuals

Deaths not uncommonly follow in young patients after frequent respiratory infections

Indications for surgical treatment. At the time of writing the number of operations being performed for atrial septal defect steadily increases Surgical closure has a decreasing mortality rate though few surgeons can match Sellors' one death in 40 operations As in all progressive branches of surgery, the initial surgical attempts were carried

out on bad risk cases Probably the patients originally selected usually those in failure or with cyanosis are now regarded as unsuitable for surgery since the mortality rate must be high and the results indifferent The progress of this surgery will be to select patients before severe deterioration has set in The selection will always depend on the fullest assessment by all means available since as already pointed out many complicating factors may co-exist which if overlooked will lead to disaster if closure of the defect alone is attempted Bailey has suggested that surgery is indicated when catheter studies have shown that the pulmonary blood flow is twice that of the systemic if the condition is left uncorrected irreversible pulmonary hypertension following permanent changes in the lung vascular system may follow

Surgical procedures available Of the operations now in use a choice could be made between those in which the septal defect is closed by blind suturing aided by the



Fig 16 1 *a*



Fig 16 1 *b*

Fig 10-1 *a* —The heart has been exposed through a bilateral thoracotomy incision with transverse division of the sternum. The pericardium has been opened widely The first stage of exclusion of the heart the passage of tapes round the caval vessels, has been done After these tapes have been tightened by pulling them up within the enclosing rubber tubes the aorta and pulmonary tubes will be occluded in a clamp placed across the transverse sinus.

Fig 10-17*b* —With the inflow and outflow tracks of the heart occluded, the right atrium has been opened the ostium secundum is being closed by suture

finger introduced through the right atrial appendage and by open cardiac surgery in which the opening is seen and deliberately closed by suture or with the use of occluding material Any surgical procedure that can be done under vision must be preferable and in the future the open method will almost certainly be the one of choice The present dangers of open cardiotomy are such however that the other methods will hold their place for a time in many clinics The main dangers of open cardiac surgery are the risks of ventricular fibrillation and of air embolism

Closed techniques Following Murray's (1948) first attempt to close atrial defects by mattress sutures passed antero-posteriorly through the heart in the region of the septum without any cardiotomy, Sondergaard (1950) applied a helpful modification The essential principle of his operation is that the groove between the two atria is dissected out so that a circular suture anchored at the top of the atrial septum close to the aorta is made to pass round the defect and is then tied to another anchored suture placed in the right ventricle just below the atrio-ventricular groove As now performed, Sondergaard guides this circumcluding suture which is drawn through mounted on a blunt probe guided by a finger placed in the right atrium He has recently described this operation in detail (1955)

Bailey (1953) introduced his operation of atrio-septopexy which invaginates part of the redundant right atrial wall into the septal defect to the edges of which it is firmly anchored by a series of sutures The operation is done through a right thoracotomy wound followed by a wide opening of the pericardium The atrial appendage is clamped and opened through an incision made in the centre of a purse-string suture attached to a Rumel snare which enables a finger to be used for full exploration of the defect and of the mitral valve through the defect Using this finger as a guide, sutures are placed through the atrial wall which are tied down to the edges of the septal defect At the end, the invaginated wall produces a "doughnut" appearance of the right atrium Blood from both the venae cavae can flow readily round the patent circle of atrium which surrounds the invaginated portion of its wall

If anomalous pulmonary veins exist, these can be deviated to the left atrium by the appropriate fashioning of the invaginated area of atrial wall Bailey (1955) gives a very full description of this in his book

Edwards (1955) has employed a mixture of the Sondergaard and Bailey techniques Having explored the defect through the right atrial appendage, a Sondergaard circular suture is placed around the defect and tied tightly enough to diminish the opening The atrial wall is then sutured down to the defect after the method of Bailey, with a finger in the atrium guiding the suture, a half-circle Mayo needle carrying a No 30 linen thread used double is carried through the atrial wall into the lower part of the septum and then through the upper edge of the septal defect and out on to the atrial wall close to the point at which it entered When a series of these sutures has been placed they are tied so that the edges of the defect are approximated and to which the indrawn pouch of atrial wall is firmly anchored . Twelve patients were explored, 11 defects closed and there were 2 deaths

This method can be used for partial closure of ostium primum defects, the lower part being left open When sutures are being placed in that area of the defect a continuous electrocardiographic record is watched for evidence of abnormalities produced by proximity of the needle to the bundle of His or the coronary sinus

Gross (1952) has effected direct suture of the defect by a method that lies half-way between open and closed cardiac surgery He sutures a well made of rubber to an incision in the right atrial wall when the clamp on the atrium is released blood recedes up to a certain point of the well A finger introduced under the blood level palpates the defect and serves as a guide to sutures placed blindly but under tactile control through the edges of the defect Kirklin has had striking results in a large series with post-operative studies by cardiac catheterization showing the effective nature of the closure

Open closure The right atrium can be opened after the venae cavae, the aorta and pulmonary artery have been temporarily occluded Such an interruption of the circulation necessitates the use of hypothermia, of a temporary mechanical pump or by the Minneapolis method Lewis and Taufic (1952) successfully closed an atrial septal defect by suture under direct vision with the aid of hypothermia and Swan has done a considerable series with few deaths under hypothermia, Brock (1955) and Ross have employed a method of hypothermia quite different from the surface cooling favoured by Swan and Lewis The method is based on rapid cooling through the venous system, this has the advantage that most of the operation up to the actual cardiotomy can be done under routine anaesthesia without the undoubted hazards of hypothermia At the appropriate moment, two catheters are introduced through the right atrium so that one lies in the superior and one in the inferior

vena cava. Before this manipulation was used, the saphenous vein was employed These are attached to a simple pump system which carried the blood from the superior vena cava through a cooling coil in the refrigerator and back into the inferior vena cava The cooling only takes 20–30 minutes and re-warming takes place while the chest is being closed

Sellors (1957) has published his results of open closure of septal defects under hypothermia there was one death in 40 patients Derra (1956) has been a bold pioneer of this method I have attempted to follow the Sellors method exactly and feel satisfied with it The method of *cooling by immersion* in a bath after Swan's method so that the temperature is about 29–30° C at the moment of cardiotomy is better in adults than the blanket method which however is applicable in children who are easier subjects to cool Sellick (1957) has given a lucid account of the details of cooling Through a bilateral thoracotomy with transverse division of the sternum the pericardium is widely opened



Fig 16-18.—After conclusion of operation for open closure of atrial septal defect through a bilateral thoracotomy incision with transverse division of the sternum. Both pleural cavities are drained by intercostal catheters, leading to a water-sealed drainage system

The superior and inferior venae cavae are mobilized and encircled by tapes which subsequently exert an occluding pressure on these vessels when they are pulled up through simple rubber tubing The right atrial wall is then explored through a small incision and a full digital examination made to confirm the site and type of defect and the position of the inferior vena caval opening a search is made for anomalous venous openings (of pulmonary veins) into the atrium and finally the finger is passed into the left atrium and the *state of the mitral valve* estimated. If it is stenosed, a digital commissurotomy is effected After this exploration the finger is withdrawn and the incision in the atrial wall is occluded by a clamp The circulation is then arrested by pulling up the tapes on the venae cavae the heart is allowed to beat 10–20 beats to empty both ventricles before a clamp is placed across both aorta and pulmonary artery through the transverse sinus The clamp on the right atrium is then removed and the small incision previously made in it greatly enlarged the two lips of the incision widely retracted and the blood in the cavity sucked out The defect in the empty atrium with no pressure on its margins is often

slit-like and easily closed by two continuous sutures starting at each end of the defect and tied in its centre * Two sutures are used in this way so that before they are tied saline can be run into the left atrium to decrease the risk of an air embolism While this saline is being run in, the anaesthetist fully inflates the lungs which fills the left atrium with blood. One of the caval tourniquets is released and when the right atrium is full of blood a large atrial clamp is placed in such a way as to close the incision The clamp on the great vessels is then removed , the atrial incision is then closed by a continuous 000 silk suture The pericardium is loosely closed and the chest closed with a water-sealed drain left in each pleural cavity Cardiac arrest or ventricular fibrillation are dealt with as described in chapter 4 The types of defect likely to be encountered are well illustrated by Sellors' diagram (Fig 16 16) The treatment of this defect when combined with pulmonic stenosis is considered on page 409

Simple pulmonary valve stenosis

Pure valvular stenosis is included under the acyanotic group of congenital heart disease because surgical treatment should be employed before cyanosis, the result of a right to left shunt through an atrial septal defect following long-standing, unrelieved right ventricular hypertrophy, has developed Here we are considering stenosis without a ventricular septal defect It is a commoner condition than realized, though not so frequent as the tetralogy of Fallot It is usually valvular in type but conus stenosis occurs This stenosis may be associated with atrial septal defect In the classical type, the valve cusps are fused to form a megaphone type of outlet , the cone of the megaphone projects into the pulmonary artery, which is thin-walled and dilated so that at operation the nipple of the valve can be palpated easily through its wall

Pathological implications. A right ventricle straining to drive blood past a narrow stenosis must hypertrophy and the supply of blood to the lungs must be diminished As the pressure of the right ventricle rises, the atrio-ventricular valve will be forced with retrograde flow of blood into the right atrium with shunting of de-oxygenated blood through a septal defect into the left atrium to produce a late cyanosis Fortunately, investigations can tell us of the state of the right ventricle before this late complication develops

Clinical features. In most children the condition is symptomless, a systolic murmur being found at routine examination, but dyspnoea on exertion may be present for years before cyanosis develops Sudden death may follow after exceptional exertion The murmur is a harsh systolic one, heard best in the pulmonary area and accompanied by a thrill , the pulmonary second sound is reduced or absent Before the right ventricle has enlarged, the heart is normal radiologically the pulmonary artery is enlarged as the result of its post-stenotic dilation and the lungs are oligaemic The electrocardiogram should show a right axis deviation if this is not so, the stenosis is probably of no great significance When the condition is advanced, a giant " a " wave is seen in the jugular pulse

The indications for surgery. If repeated electrocardiograms show an increase of right ventricular strain, surgery is obligatory Confirmation of the E C G findings can be provided by studying the results of cardiac catheterization If the systolic pressure is over 50 mm of Hg and the gradient across the valve shown to be considerable, valvotomy should be advised To decide whether the stenosis is valvular or subvalvular, diodone

* In placing the lower suture meticulous care is necessary to avoid including part of the inferior cava as this can deviate unsaturated blood to the left atrium

is injected through the catheter as it lies in the right ventricular outflow tract and cardiograms made If cyanosis has developed surgery is urgently indicated it is in such late cases that the operation carries a mortality risk The risk of the operation in acyanotics is almost negligible

The operation of pulmonary valvotomy

The classical Brock operation is now rarely used The incision is an anterior thoracotomy one performed through a curved infra mammary incision which is not carried too high up into the axilla The pectoral muscles and the overlying breast are dissected free from their lower thoracic attachment and held upward in a moist saline pad this

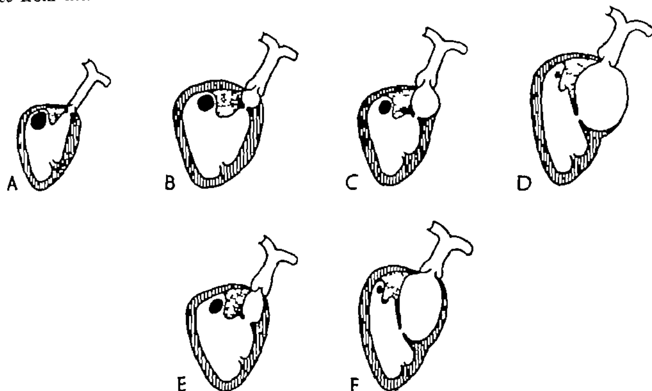


Fig 10-19 —The commoner types of infundibular stenosis. In (A) there is a high degree of pulmonary hypoplasia with a bicuspid valve and stenosis lying just below the valve in a narrow muscular channel. In (B) the commonest type there is a high infundibular chamber with a very thin fibrous wall. In (C) there is a small infundibular chamber with a very thin fibrous wall. In (D) the thin walled infundibular chamber is large In (E) and F) two types of infundibular stenosis are shown, similar to those in (C) and (D) except that the outer wall of the infundibular chamber is muscular (Brock and Campbell, *British Heart Journal*)

dissection must be meticulous and thorough so that a clear view of the third intercostal space is obtained The pleural cavity is opened through this space almost as far back as the angle of the rib the third and fourth costal cartilages are cleared thoroughly and divided a little away from the sternum with rib spreaders in place an excellent exposure is obtained the left lung which is kept inflated by the anaesthetist throughout the operation is held posterolaterally by a light retractor Overlying fibro fatty tissue is dissected off a wide area of the pericardium this is essential to allow a wide pericardial flap to be fashioned for periodic gentle traction on this flap may be required in the operation when it may be desired to bring the heart well over to the left for brief periods

The pericardium is opened widely just in front of the phrenic nerve A large flap is created hinged medially after horizontal incisions have been made above and below this flap can then be held by an assistant drawing on a series of linen threads on silk stay sutures

so placed that effective traction upwards and to the left can be made on them when the operator wishes to bring the heart to the left, but heavy or prolonged traction must be avoided sedulously as it interferes severely with cardiac action If the pulse alters or tachycardia develops the traction is released at once and constant attention was paid to this point by Brock A small incision is made into the right ventricle, a little below the site of the infundibulum of the pulmonary artery The incision stops just short of the endocardium, the first entry into the chamber of the ventricle being made by the special curved probe , this probe is passed up into the area of the valvular obstruction and is guided on through it to make the first real passage When the probe is withdrawn, finger pressure is applied to stop bleeding , the special valvotome is then passed into the valve which is divided at once With suitable pauses, the valvotomy tears are enlarged by the passage of graduated bougies, the final splitting being achieved by the dilator

Brock is insistent on the need to produce lateral cuts in the valve so that competent flaps will be left which prevent any pulmonary regurgitation The incision is closed by silk sutures passed beneath the tip of the index finger which occludes the hole in the ventricle In a straightforward case bleeding is minimal , pressure should be maintained on the cardiotomy opening for several minutes before any attempt is made to pass the sutures , by this means alone the bleeding often ceases spontaneously and the stitches can be placed at leisure Pressures taken in the right ventricle and in the pulmonary artery before and after the valvotomy enable a guide to be given to the surgeon as to the efficacy of his attempts. The pressures can be taken easily by a hollow probe, connected to the electro-manometer, passed from the ventricle across the valve into the pulmonary artery

Modifications of the original Brock operation

I *The approach through the chest wall* Usually the right ventricle, because of its hypertrophy, projects so well into the left pleural cavity that cardiotomy can be done without difficulty If, however, this is not so and additional access is required, the sternum is divided at the anterior end of the incision and separated by the use of a Tuffier retractor

II *Valvotomy through the pulmonary artery* Most surgeons believe that a better valvotomy can be done from above through the pulmonary artery If the operation through the artery is a blind one, it seems difficult to imagine that a better splitting of the valve would be obtained Swan (1955), however, dissatisfied with transventricular valvotomy because the fall in right ventricular pressure was not to normal nor near it in most recorded series, decided to employ valvotomy under direct vision through the widely opened pulmonary artery He reported 12 cases with no deaths Hypothermia is used to provide additional safety * Through a bilateral transpleural and trans-sternal approach the venae cavae, the pulmonary artery and the aorta are prepared for temporary clamping the pulmonary artery is then opened and the valve deliberately incised with scissors by two in two directions up to the valve ring A finger is then passed into the right ventricle to exclude an associated infundibular stenosis (Fig 16 19) If this is diaphragmatic in type it can be disrupted Muscular hypertrophy may be due to the valve stenosis Resection of such muscle masses should not be undertaken lightly A lateral clamp is placed on the pulmonary artery to close the wound in it after Ringer's solution has been poured in to remove air from its lumen the occluding devices on the venae cavae, the pulmonary artery and the aorta are then removed in rapid succession The *manœuvre* can be completed in less than two minutes and the pulmonary artery is then deliberately closed

* Ronald Edwards does open valvotomy at normal temperatures with the venous return to the heart occluded for less than two minutes I have found this to be excellent

Pressure studies at the time of operation and later showed that the right ventricular pressure had been reduced 100 per cent in six cases so studied My own preference is for open valvotomy

III *Pulmonary valve stenosis with atrial septal defect* Not uncommonly pulmonary stenosis is combined with atrial septal defect the pre-operative diagnosis of this double anomaly can be established by catheterization and the gradient across the pulmonary valve established If the pulmonic obstruction is a severe one the right ventricle under the burden of an increased blood flow reaching it through the septal defect while the shunt remains as a left to right one will rapidly hypertrophy The reversal of the shunt will follow when the tricuspid valve becomes functionally incompetent Under such conditions the need for surgical treatment of both defects is urgent ideally surgical treatment should be sought long before such cyanosis develops Under hypothermia and through the usual bilateral thoracotomy incision the circulation into and out of the heart is arrested and the pulmonary valve stenosis relieved by an approach through the pulmonary artery After this has been completed the circulation is restored and a pause of 15 minutes allowed before the circulation is occluded a second time to allow open surgery for closure of the atrial defect

In patients without cyanosis the same line of treatment will be adopted if the gradient across the pulmonary valve is considerable (30–40 mm Hg) If the pre-operative catheter findings however suggest that the pulmonary obstruction is slight direct pressures from the ventricle and pulmonary artery should be taken Should these show only a slight gradient with a normal pulmonary artery pressure the atrial septal defect alone should be closed

The results of valvotomy for pure pulmonic stenosis

The main criticism of pulmonary valvotomy has been that although pulmonary blood flow is obviously increased the condition of the right ventricle improved as shown by post-operative electrocardiographic studies and cyanosis when present has been relieved the fall of pressure in the right ventricle has not been altogether satisfactory The pressures in the right ventricle following transventricular valvotomy have been shown by post-operative studies to have been reduced by half or more (Campbell and Brock) Open operation by Swan s method has clearly solved this problem of the ventricular pressure but may be followed by pulmonary regurgitation It remains to be seen yet whether the long term result of patients with a dramatic drop in ventricular pressures but with pulmonary regurgitation will be better than in those with partially relieved stenosis but without regurgitation In principle it seems that an operation done under direct vision will ultimately provide the best results Finally a study of published series shows that valvotomy done before cyanosis has appeared will give good immediate results with a very low mortality rate cyanosis itself will be relieved invariably

VENTRICULAR SEPTAL DEFECTS

Encouraged by the success of Lillehei and his colleagues (Warden 1957) and of Kirklin (1957) in the surgical treatment of ventricular septal defects the scope of cardiac surgery has been greatly extended Whether considered as an isolated defect or in combination with other anomalies such as the tetralogy of Fallot canalis atrio ventricularis ductus arteriosus coarctation of the aorta etc it is a common congenital lesion Maude Abbott s examination of 1000 autopsy specimens of congenital heart disease revealed 274 ventricular

septal defects and 373 atrial ones In the field of congenital cardiac disease it provides the most important indication for open cardiac surgery performed with the help of extra corporeal circulation In this chapter we are concerned with those patients without cyanosis It can no longer be accepted that isolated ventricular septal defect is a relatively





FIG 16 20 FIG 16 21

FIG 16 20 —Ventricular septal defect in the tetralogy of Fallot The right ventricle has been opened the defect, marked X, is in the high, classical position The prop seen is holding open the walls of the dilated infundibular channel which leads to the obstructed area above it

FIG 16 21 —The most complete type of " ostium primum " defect (canalis atrio ventricularis communis) Above the tricuspid and mitral valve, which are in the form of a continuous sheet, lies a large atrial septal defect below the valve area is a large defect in the ventricular septum The difficulties inherent in the repair of such an anomaly are obvious

benign condition, for many die in childhood and few live beyond early middle age If the opening is more than 1 cm in size the patients are frequently in hospital either with attacks of cardiac failure or with recurring bouts of severe respiratory infection. Pulmonary hypertension may develop very early in life Many of the patients therefore require surgical correction in early life, as operations carried out in patients with severe pulmonary hypertension will always carry a formidable mortality rate

The site of the defects

As Lillehei points out, Rokitansky (1875) provided an admirable classification the extreme example is absence of the septum (single ventricle) The patency may be in the posterior or anterior part of the septum In both of these sites the aortic and pulmonary

trunks may be normally or abnormally sited for example the front half of the septum may be absent with normal great vessels or in association with obstructive lesions of the pulmonary artery (tetralogy of Fallot) conditions which may accompany deficiencies in the posterior part of the septum In isolated defects the surgeon may be fortunate to find a defect only in the anterior part of the anterior septum or (rarely) one in its lower muscular part. More usually he must expect an opening high up just below the pulmonary valve or below the crista supraventricularis partly hidden by chordae tendineae going to the tricuspid valve either in the inflow or outflow track of the right ventricle Many defects lie in that part of the outflow track of the right ventricle which is inferior to the crista supraventricularis The fact that defects may be multiple demands a close scrutiny of the whole septum to avoid overlooking patencies which if left unclosed will mar the effectiveness of the repair

The proximity of the valve ring of the aorta (especially vulnerable in the repair of the high defect) and of the papillary muscles going to the septal leaflet of the tricuspid valve which require retraction during the repair must constantly be in mind The conduction system usually lies close to the postero-inferior margin of the septal defect if picked up by the sutures used in closure heart block may be a serious post-operative sequel The bundle of His and its branches are specially vulnerable during the closure of defects in the outflow track that are inferior to the crista supraventricularis The higher up the defect is in the septum, the less likelihood is there of damage to the conduction system fibres such defects in the outflow track of the left ventricle lie immediately below the pulmonary valve

The pre-operative investigations

Before surgery is employed the fullest cardiological examination is essential to exclude the mimicry of other defects e.g a ductus arteriosus with a systolic murmur only and even more particularly to exclude associated defects such as atrial septal defect atrio-ventricularis communis and coarctation of the aorta We have seen these associations several times at the Children's Hospital Whenever possible such associated anomalies should, if possible be corrected at the time of the operation on the ventricular septum If a ductus was overlooked before the cardiotomy disastrous haemorrhage could ensue in the absence of pulmonary artery occlusion bleeding from the coronary sinus in a patient with an overlooked left superior vena cava would be severe until the anomalous vein had been temporarily occluded. However careful the pre-operative estimations a full exploration of the heart and surrounding great vessels by examination and palpation must be done before the cardiotomy

A knowledge of the degree of pulmonary hypertension is of great value If surgery is employed on patients with a severe degree of this death is common before closure of the defect the left ventricle has contributed largely to the cardiac effort as it drives blood through the damaged pulmonary vasculature The long and sorely tried right ventricle may be unable to take over this burden and may fail Attempts to diminish the pulmonary blood flow by partial surgical occlusion are being used as a preliminary in the hope of allowing the patient to survive at a later operation the closure of the ventricular septal defect Surgery should if possible be done before the pulmonary vasculature has become seriously damaged

The surgical closure of the defect

Through the classical bilateral anterior thoracotomy the artificial circulation is established (page 29) The right ventricle is opened widely preferably after the induction of

cardiac asystole by the injection of potassium citrate into the aorta after it has been clamped off close to the coronary arteries With the lips of the incision in the ventricle widely held apart by stay sutures, the whole area of the septum is carefully examined and the relation of the defect to the aortic and tricuspid valve cusps assessed If the defect, as is usual, lies in the ventricular outflow track postero-superior to the crista supraventricularis the chordae tendineae are retracted downwards , above the defect the aortic cusps will be seen The ventricular septal defect can often be closed by sutures if good bites of sound tissue are made , sometimes polyvinyl sponge is used as a patch, sutures of 2–0 silk grasp one side of the defect, pass through the selected piece of the sponge and then across the edge of the other side of the defect These sutures are passed and tied in such a way that they appose the edges of the defect together with interposition of the sponge The greatest care is taken to avoid picking up a portion of the aortic valve cusp As the conduction tissue lies in or near the postero-inferior edge of the right side of the defect, this area is avoided as far as possible as a place for a suture Heart block after this operation has been a serious problem in many clinics Full details regarding many technical details are given in the papers of Kirklin (1957) and Lillehei (Warden, 1957) There seems no doubt that in the closure of ventricular septal defects suture alone will often suffice and few require fortification by polyvinyl sponge (Ivalon)

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CHAPTER 17

CONGENITAL CYANOTIC HEART DISEASE

Surgeons are concerned mainly with patients exhibiting central cyanosis due to a right to left shunt associated with a poor blood supply to the lungs Cyanosis due to the reversal of a previous left-to-right shunt, e g atrial septal defect, ductus arteriosus, has been described in the previous chapter The tetralogy of Fallot represents about 70 per cent of all instances of cyanotic congenital heart disease , surgery in this condition has made important progress by increasing the blood flow to the lungs by the Taussig-Blalock indirect method whereby a systemic vessel, usually the subclavian artery, is anastomosed to the pulmonary artery or by the modification introduced by Potts of anastomosing the aorta to the lung artery , by direct attack on the infundibular or pulmonary valve stenosis (Brock, 1955) and by Lillehei and his colleagues who, first using cross-circulation from a donor and then by the use of a pump oxygenator, were able by direct open cardiac surgery to close the ventricular defect and at the same time remove the obstruction to the right ventricular outflow system This method removes the right-to-left shunt and the obstruction to the right ventricle virtually leaving an almost normal heart and offering a longer life expectancy than the other two methods Blalock's operation has stood the test of time for a follow-up of over ten years in some instances but the creation of another shunt, though giving obvious immediate benefit, adds a further burden to the deranged heart and must be a factor in leading to ultimate heart failure

Of the less common causes of cyanosis in this group, tricuspid atresia, atresia of the main pulmonary artery stem (with patent vessels beyond) and persistent truncus arteriosus can be alleviated by Blalock's operation Transposition of the great vessels remains a common cause of death in infants but so far provides a formidable problem in spite of Blalock's, Mustard's and Baffe's (1957) determined work in this field Late cyanosis in patients with pure pulmonic stenosis when the foramen ovale or a septal patency has been forced can be treated by pulmonary valvotomy , in such patients the Blalock procedure is contra-indicated (page 409)

At the moment the real solution to the problem of the tetralogy of Fallot seems to lie with deliberate, corrective open cardiac surgery on the chemically arrested, by-passed heart The avoidance of any less radical operation by surgeons, until their own organization is *equipped with adequate extra-corporeal circulations systems,* would seem wise whenever possible The description in this chapter of other operations is still included but such procedures are obsolescent and should only be employed after the most serious consideration of each individual patient There will probably always be a place for the indirect operations in tricuspid atresia and truncus arteriosus

The tetralogy of Fallot

The classical type shows a high interventricular septal defect, with the aorta overriding both ventricles, hypertrophy of the right ventricle and stenosis or atresia of the pulmonary artery or of its infundibulum The last abnormality was the most important in the days when the only surgical objective was to augment an inadequate pulmonary blood flow, by anastomosing a systemic artery, such as the subclavian or the aorta, to the pulmonary

artery or by a direct attack on the site of stenosis Heart lung bypass procedures now permit more radical surgery The differentiation of valvular stenosis from infundibular obstruction is not easy even with the most excellent angiocardiography pictures (Chap 14) At the moment of writing there is little doubt that surgical division of a stenosed valve (valvotomy) is a safer procedure than resection of an infundibular obstruction and that both procedures are being superseded by open cardiac surgery

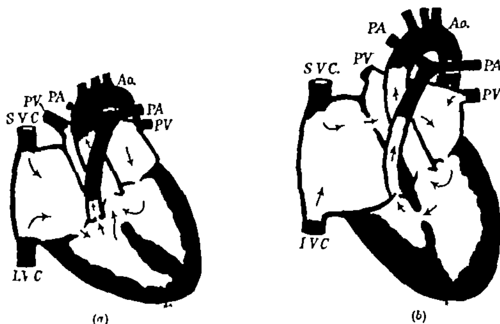


Fig 17 1

(a) Diagram of tetralogy of Fallot

Showing interventricular septal defect overriding aorta stenosis of pulmonary artery and hypertrophy of right ventricle

(b) Tricuspid atresia with rudimentary right ventricle

A Taussig-Blalock operation is also employed in this condition.

Clinical features Once cyanosis develops (it may be present at birth or develop later) it becomes progressively severe it is seen most easily in the tongue lips lobes of the ears and in the clubbed fingers and toes The infants or children grow slowly are underweight and tire easily they become breathless on exertion though the exercise tolerance varies considerably according to the severity of the defects The children are often intelligent and of pleasant personality The peculiar habit of squatting is typical of patients with a defective blood flow to the lungs Polycythaemia is present

Bouts of unconsciousness are common and follow unexpected demands on the inadequate oxygen in the blood stream after attacks of anger or sudden exercise especially in the morning As in all congenital cardiac lesions there is an ever present danger of infective endocarditis pulmonary tuberculosis and cerebral abscess are relatively common associates The most trivial procedure such as teeth extraction must always be done with antibiotic protection The heart though altered in shape is not usually enlarged and there is a basal systolic murmur accompanied by a thrill in half the patients with a normal or diminished pulmonary second sound

Radiology The heart is often boot shaped being tilted up to the left because of the hypertrophy of the right ventricle with a concavity in the pulmonary artery area and clear lung fields indicative of a poor blood flow through the pulmonary artery Radiological screening demonstrates hypertrophy of the right ventricle and unusual clearness of the pulmonary window the area seen in the left anterior-oblique position behind the main

pulmonary artery, below the arch of the aorta, the pulsations of the pulmonary arteries in the hilum of the lung are slight or absent In 25 per cent of the patients the screening will show the aorta descending on the right side and this can be confirmed by noting that the aortic depression on the oesophagus when barium is swallowed faces to the right and not the left and by angiocardiography

The electrocardiogram shows a right axis deviation and the physiological adaptation

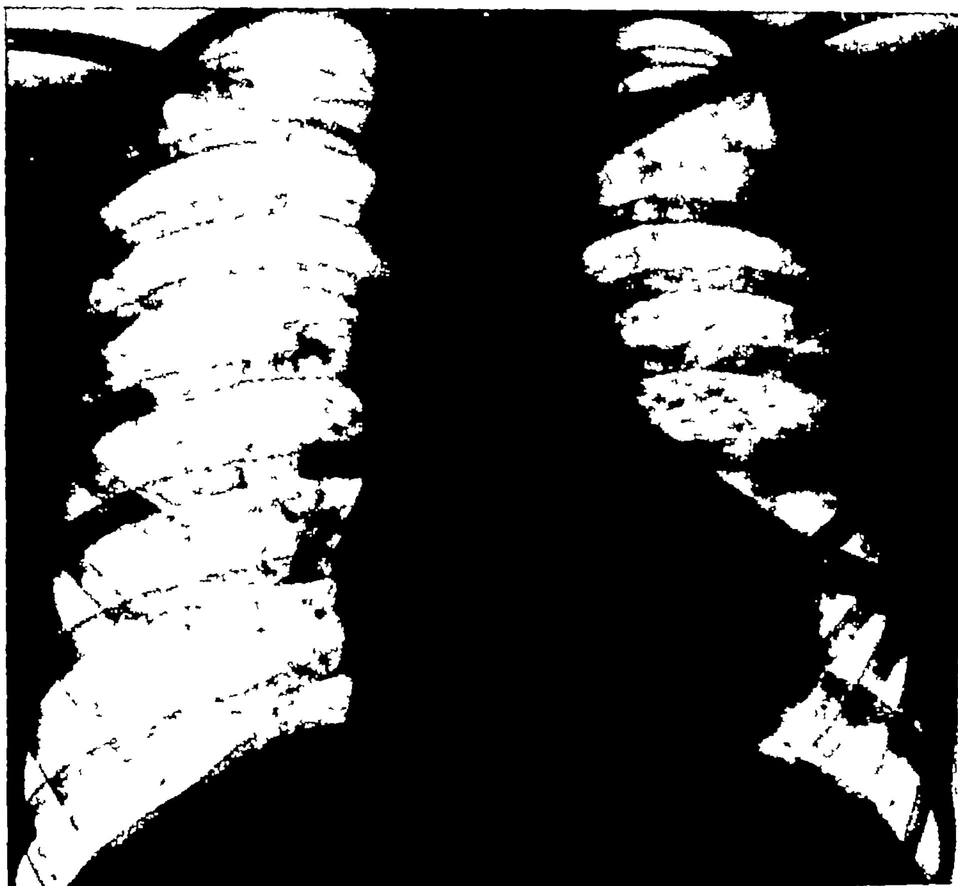


FIG 17 2 —Radiograph of a patient showing the boot-shaped heart characteristic of Fallot's tetralogy A left-sided Blalock anastomosis has been done The thoracotomy was performed through the bed of the resected fourth left rib which has partly regenerated

of the blood to a deficient oxygenation is reflected in a high red blood cell count of from $6\frac{1}{2}$ to 10 millions with a proportionate rise in haemoglobin of the normal 100 per cent to 120–180 per cent, the oxygen saturation of the arterial blood is low and may be down to 30–50 per cent in severe cases

Confirmation of the diagnosis Since every cyanotic congenital heart patient with pulmonic stenosis and an intracardiac right-to-left shunt can theoretically be helped by surgery the essential pre-operative need is to prove that poor pulmonary blood flow exists. The clinical features just described usually provide this information, of all the investigations the estimation of the presence, absence or diminution of the blood flow in the pulmonary artery is a most important fact to be established In the typical Fallot patient the diagnosis is usually certain after clinical and radiological examination, but great assistance in its confirmation can be obtained from angiocardiography and cardiac catheterization (Chapters 14 and 15)

The exact anatomical pattern is shown by angiocardiography and the exact pressure

within the pulmonary artery and the outflow tracts of the right ventricle is estimated by the catheter studies Direct observations at operation enable differentiation of a valvular from an infundibular stenosis

The value of angiocardiography Screening and cardiac catheterization will establish the diagnosis and provide a pre-operative estimate of the pressure in the pulmonary artery and confirm the presence of or absence of a pulmonary artery if a systemic pulmonary anastomosis is contemplated the anatomy of the aorta should be delineated Anomalies of these are frequent and it is important to know whether there is a suitable subclavian artery on one or other side that is large and long enough for anastomosis to the pulmonary artery Good angiocardiograms will give this information and may save a faulty choice of side for thoracotomy It also has considerable diagnostic value and proves the presence of a right-to left shunt and gives an estimate of the amount of blood that passes directly from this shunt into the aorta and of the diminution of flow into the pulmonary artery (See Chapter 14)

Differential diagnosis

Diagnosis of the classical Fallot defect is not usually difficult In the Eisenmenger complex the defects of the Fallot heart exist but there is no pulmonic obstruction and the lungs are fully supplied with blood There will be no cyanosis until the pulmonary plethora caused by the left to right shunt produces a degree of pulmonary hypertension sufficient to reverse the flow this is accompanied or possibly preceded by a pathological occlusion of the pulmonary vascular bed In the Eisenmenger defect the pulmonary arteries will be large and no relief will follow a Blalock operation If doubt exists as to the diagnosis cardiac catheterization will reveal a high pulmonary artery pressure

Tricuspid atresia is rare A large right atrium a diminutive right ventricle and poor blood flow can be seen The electrocardiograph shows a left ventricular preponderance Life may be dependent on a persistent ductus arteriosus or an interatrial septal defect and when this is so the pulmonary artery itself is atretic Cyanosis usually exists from birth and the general pictures characteristic of its imitator the Fallot are present

Truncus arteriosus provides a single large trunk arising from the base of the heart sometimes with part of the aortic septum present The degree of cyanosis depends on the amount or deficiency of lung blood flow Radiologically the heart is large with a gross exaggeration of concavity in the area of the pulmonary arc The lungs are oligaemic and may be supplied almost or entirely by the bronchial arteries Cardiac catheterization is usually required to make the diagnosis the blood in the ventricle will have the same oxygen content as systemic arterial blood and the catheter itself cannot be coaxed into the pulmonary artery Angiocardiography will show immediate aortic filling If there is stenosis of the pulmonary artery blood may be seen entering the lung very slowly through enlarged bronchial arteries

Transposition of the great vessels is a commoner abnormality than often thought as most of the infants die shortly after birth though a few survive months or years to provide a diagnostic problem The cyanosis usually starts at birth and there are associated abnormalities such as septal defects or ductus arteriosus which allow life to proceed Early cardiac enlargement usually with full lung vascularity contrast with the appearances seen in a Fallot s tetralogy The best method of diagnosis is by angiocardiography (p 330)

Surgical treatment of transposition of the great vessels

In this serious malformation the aorta arises from the right ventricle the pulmonary artery from the left the pulmonary and systemic veins emptying normally into the left and right auricles

respectively Life is possible because the complete separation of the greater and lesser circulat is overcome to some effect by the existence of an interventricular septal defect Blalock's (1 operation aims at increasing this mixture by creating an opening between the two auricles, left-sided wall of the right auricle has a septum common to it and the right pulmonary vein that after temporary occlusion of the pulmonary artery and of the right pulmonary veins opening can be made into this wall so that the systemic venous and pulmonary venous bl can mix The logical conclusion, if the patient is fit to stand the extra intervention, is the crea of an artificial ductus Further work is proceeding on this subject in Blalock's clinic

In addition to the formidable anatomical defects there is a severe degree of pulmor hypertension and the coronary artery blood supply is a precarious one as it receives only ver blood from the aorta which is arising from the right ventricle Perhaps the best results wo follow a surgical transposition of the systemic and pulmonary veins but such procedures formidable and would involve many suture lines Such operations performed on the cadave adults have taken over two hours

Blalock and Hanlon (1950) pointed out that if no obstruction exists in either circula then the object of surgical treatment is to let blood pass from one circuit to the other anterior wall of the right superior pulmonary vein is covered by the right atrium and aft temporary clamp has been placed on the pulmonary artery the right superior pulmonary is isolated and temporarily occluded on its pulmonary side A special clamp is then placed the right auricle in the region where the superior pulmonary vein enters it An incision is m into the superior pulmonary vein and carried on to the auricular wall and an opening crea into the vein as it passes behind the atrium An atrial septal defect is produced and the opera completed by anastomosing the proximal end of a subclavian artery to the distal end of a pulmon artery Baffes (1957) has succeeded in improving greatly 19 patients out of 38 operated up His ingenious operation depends on transposing the right pulmonary veins and the inferior v cava, so that they drain into the other atrium The right pulmonary artery and veins, the infe vena cava and the right main bronchus are dissected, ready for later occlusion If there is no monary stenosis (demonstrated by observing the pressures in the artery), a curved clamp hav taken up a bite of the inferior vena cava, an incision is made into it To the lips of this inci an aortic graft is sutured A clamp is placed on the entrance of the right pulmonary veins i the left atrium after the pulmonary artery has been temporarily occluded to prevent lung c gestion, the pulmonary vein stem is divided between clamps and the aortic graft sutured to distal end as it lies proximal to the clamp blood later will flow from the inferior vena cava the graft into the left atrium The pulmonary end of the right pulmonary vein is then anastomo to the right atrium after an incision has been made into that chamber after part of its wall been held in a curved clamp The temporary clamping of the pulmonary artery is released the right lung fully re-aerated A silk ligature is then tied round the entry of the inferior v cava into the right atrium so that all the blood entering this vessel is now deviated via the gr into the left atrium, while the right pulmonary veins have been deviated to the right atrium, t greatly increasing the passage of oxygenated blood into the right ventricle and so on into aorta, while more unsaturated blood from the inferior vena cava reaches the left side of the he for onward delivery to the lungs

Surgical treatment in congenital cyanotic heart disease

The surgical treatment of the tetralogy of Fallot is changing rapidly from the positi in which the main aim was to increase the blood flow to the lungs by Blalock's or Pot operation, an intermediate phase was the development of Brock's operation for the dire relief of infundibular or valvular stenosis The final phase is the evolution of cardiop monary by-pass which enables the surgeon to open the potassium arrested heart, close t ventricular defect and remove obstructions in the outflow track of the right ventricle Vascul anastomoses are still required for the relief of tricuspid atresia and the truncus arterios

The age for operation As many die before the age of 6, surgery is often indicat at about the age of 3 at this age the systemic vessels are large enough to enable adequa by-pass circulations to be established although this is easier in the older child Occasio ally a patient will not survive even to the age of 3 and then an anastomotic operation m

be necessary to save life this should however be avoided whenever possible Continuous persistent medical treatment may tide over even the worst cardiac cripples to an age when full corrective surgery is possible

Four operative procedures are available The first three are obsolescent

(1) The Taussig Blalock anastomosis of a large systemic vessel to the pulmonary artery preferably by end to-side anastomosis which increases the blood flow to both lungs The ideal vessel is the subclavian artery as the use of the innominate or carotid vessels lays the polycythaemic child open to the grave danger of cerebral thrombosis The operation is now used mainly for patients with tricuspid atresia

(2) The Potts modification of Blalock s operation This involves a side-to-side anastomosis of the aorta to the pulmonary artery An ingenious clamp allows the aorta to be clamped in such a way that blood still flows through the main channel leaving the segment selected for the anastomosis distal to the clamp Potts operation provides a better blood flow to the lungs the anastomosis does not thrombose and it has given excellent results in very young children or infants when failure after the use of a small subclavian artery has been common there is a tendency to make the opening too large thereby placing a great strain on the left ventricle The aortic incision should be a quarter to three-eighths of an inch in length according to the stature of the child If at a later date closure of the ventricular septal defect has to be done because of increasing enlargement of the heart the undoing of this anastomosis would indeed be formidable For this reason it is difficult to think that this operation which has provided brilliant results will be done much in the future when in addition to relief of pulmonic obstruction closure of the septal defect will be the object

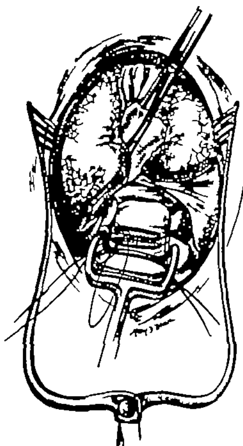


Fig 1~3 —Potts operation.

The left pulmonary artery has been temporarily occluded by two stout ligatures which encircle the vessel twice without being tied. The aorta has been partially occluded by Potts clamp and the first layer of the anastomosis is partly completed.

(3) *Brock s operation* This logical operation aims to fulfil the general surgical principle that obstructive lesions whenever possible should be relieved at the site of stenosis and is free from the objection levelled against the Blalock procedure that it increases the burden of a deranged heart by creating an arterio-venous fistula distal to it Brock has devised two procedures one being a pulmonary valvotomy and the other a resection of the hypertrophied muscular bands in the infundibulum

(4) *Closure of the ventricular septal defect and relief of the pulmonic stenosis by direct vision intracardial surgery* This ambitious technique was first successfully achieved by Lillehei (1955) who reports operations on 40 patients by direct vision procedures during the cardiotomy which lasted for periods of between five and forty minutes the lungs were by passed by the use of donor circulations (controlled cross-circulation) or by continuous arterial perfusion from a reservoir of arterialized venous blood Of this series of operations done on seriously ill patients 26 survived in ten of them with the tetralogy of Fallot the ventricular septal defect was sutured and the infundibular stenosis resected with six survivors Many more have since been done with success

At the time of writing this, work is proceeding with astonishing speed; the cross circulation method has been abandoned in favour of continuous arterial perfusion of oxygenated donor blood and the methods have passed from the experimental stage into practical everyday surgery in Minneapolis, the Mayo Clinic and elsewhere. A brief description of the methods of extracorporeal circulation has been given in Chapter 13. It seems certain that open cardiac surgery for the tetralogy will replace all other methods. With the heart by-passed and arrested by potassium citrate or acetyl-choline the right ventricle is opened widely. The obstruction to the pulmonary artery, whether it be due to valvular or infundibular stenosis, is dealt with radically. This may require enlargement of the outflow track at the closure of the cardiotomy incision by suturing in a piece of Ivalon to replace direct suture of the two lips of the incison in this area. The septal defect, which is usually high up on the septum or below the crista supraventricularis (page 410) is closed by sutures or polyvinyl sponge. This correction calls for a detailed knowledge of the anatomy of this difficult area. This has been admirably supplied by Kirklin (1957); it is not possible or fair to attempt to summarize this paper, which should be read by anyone engaging in the closure of ventricular septal defects with or without the presence of the other defects of the tetralogy of Fallot. Warden (1957) reporting the experience of the Minneapolis group with ventricular septal defects includes a full account of this condition when it is part of the tetralogy of Fallot.

The Blalock-Taussig operation *

Selection of the side and type of exposure. In his first large series of patients Blalock advised operating through the side of the chest opposite to the aortic arch, because the divided subclavian artery coming off the innominate trunk can be turned down to the pulmonary vessel in a curve which appears far more efficient than the angled appearance of the divided left subclavian artery, which has to be turned down from the aortic arch. In many patients, however, the use of the subclavian artery that arises directly from the aorta is fully efficient, in spite of the apparent kink noted at the end of the operation, and many surgeons select the left side, provided the pre-operative estimate (made largely on angiocardiography) has demonstrated a reasonably large vessel on that side. The advantage of the left side is that there is no troublesome superior vena cava in the way of the mediastinal dissection and that the left-sided subclavian vessel is longer than its fellow on the right. In about 25 per cent of these patients the aorta descends on the right side (as proved by pre-operative radiology) and then the perfect condition for a left thoracotomy exists because the angle formed by the downwards placed subclavian artery is less acute than when it arises directly from the aorta.

Pre-operative measures. The child should be long enough in the surgical ward to have become accustomed to the nursing staff and to have received training in the physiotherapeutic measures which will play an important part in the post-operative phases. Part of the day is spent in an oxygen tent to avoid its being a frightening enclosure post-operatively. A high fluid intake must be maintained because of the great danger of dehydration in a polycythaemic child and as a measure of training for the necessary post-operative forcing of fluids. Parenteral penicillin is commenced on the day before operation.

Anaesthesia. The tolerance of these cardio-respiratory cripples to anaesthesia is astonishing. During the operation the surgeon requires the quietness of respiration that can only be obtained by controlled respiration; curare or muscle relaxants being used

* Though probably obsolescent, this operation and the Potts procedure is described because of its value in the treatment of tricuspid atresia and truncus arteriosus with pulmonic stenosis.

after induction by pentothal and anaesthesia maintained by nitrous oxide and oxygen the curare dosage must be so estimated that rapid recovery ensues and that at the close of the operation the cough and the pharyngeal reflexes are present

When the child has been gradually anaesthetized with the minimal degree of barbiturate narcosis an intratracheal tube is passed An extraordinary feature often noted is that the colour of these patients improves as soon as a satisfactory anaesthetic relaxation has been achieved the reason for this is probably the decreased call for oxygen by the tissues but the lungs of these patients probably take up more oxygen even though oxygen uptake theoretically is already at its highest

A slow dextrose intravenous drip is maintained throughout the operation to decrease the risks of dehydration as these polycythaemic patients are naturally liable to thrombosis Blood transfusion is not employed but it must be available in case of a severe haemorrhage through a technical accident

The operation With the patient in the classical lateral position the fourth intercostal space is opened After the pleura has been opened the lung on that side is not allowed by the anaesthetist to collapse it is better to displace a partially inflated lung throughout the operation by a moist saline swab to which sufficient retraction is applied than to allow it to collapse

The assessment of the local conditions

Whatever the pre-operative plan immediate modification of it may be necessary after a visual and digital examination of the right ventricular outflow track and of the systemic vessels has been carried out If after the pericardium has been opened a pure valvular stenosis has been demonstrated a decision to employ pulmonary valvotomy may be made This state can be accurately diagnosed with a valvular stenosis the pulmonary artery beyond shows the classical post-stenotic dilatation and the nipple-like valve can be felt projecting into the thin wall and delivering a thrill to the palpating finger Such a finding would induce many to proceed at once to pulmonary valvotomy (See page 407)

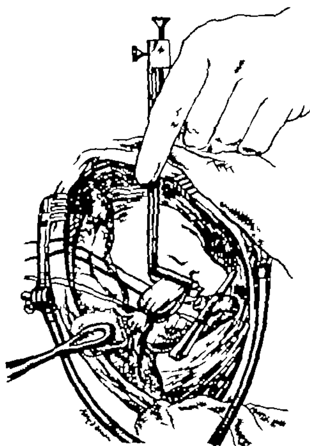


Fig 1~4 —Blalock s operation.

The pulmonary artery has been occluded proximally by Blalock clamp distally by a loose encirclement by a silk ligature (not tied) The mobilized and divided subclavian artery has been clamped with bulldog arterial clamp preparatory to its anastomosis end to side to the pulmonary artery

Infundibular stenosis does not produce such a degree of post-stenotic enlargement of the artery Variable appearances may be met with if the stenosis is low the outflow track beyond it may be dilated to give the appearance of a third ventricle such a stenosis may be associated with a higher obstruction or a valve stenosis The exact site of the stenosis is best estimated by taking direct pressure readings in the right ventricle and passing the cannula up into the pulmonary artery noting the site at which the pressure as recorded on the mercury manometer shows an abrupt fall this site is confirmed by palpation The infundibulum may be very small and this would

indicate the need for most surgeons to proceed to an indirect rather than a direct operation Brock, however, has pointed out that such a small outflow track might enlarge after relief of stenosis proximal to it (Fig 17·5 here)

The condition of the main pulmonary artery plays an important part in aiding the surgeon to select the operative procedure a hypoplastic or atretic main stem indicates the need for a by-pass operation rather than a direct attack before open cardiac surgery developed Lillehei has pointed out that the smallest pulmonary artery after closure of the ventricular septal defect will enlarge

The condition of the subclavian artery will enable a decision to be made for or against using it for the anastomosis If it is small or absent, a decision to use the aorta would be made If conditions are favourable for a Blalock operation, the following steps in the operation are taken

Exposure of the pulmonary artery This may be easy or difficult depending on the absence or presence of collateral veins in its sheath The sheath is opened thoroughly from the pericardial reflection medially and well into the lung laterally so that the major branches of the vessel are clearly seen The adventitious tissue must be thoroughly separated from the artery by a mixture of blunt and scissor dissection , this is greatly facilitated by placing umbilical tape round the vessel as soon as an adequate space has been secured for its passage , elevation of the tape held in forceps enables the posterior wall of the vessel to be cleared A long length of the vessel and its first two branches are freed completely from all fascial investments , a rubber-shod Blalock clamp is then placed on the proximal side of the artery and the effect of its closure noted If the patient is not unduly disturbed it is clear that the pulmonary artery on the other side is carrying sufficient blood to enable a satisfactory respiratory exchange of gases to be maintained the clamp is then loosened and attention paid to the systemic artery to be selected for the anastomosis

Exposure of the systemic artery In the absence of gross abnormalities of the distribution of the aortic branches, the exposure and clearing of the subclavian artery is an easy procedure. The mediastinal pleura over it is divided freely from the level of the aorta up to the division of the artery , a small vein usually crosses the vessel just before it divides into branches and this is doubly ligated and divided If the aorta is right-sided the recurrent laryngeal nerve is isolated carefully, as it comes off the vagus nerve to pass round the origin of the subclavian artery as it leaves the innominate trunk When the subclavian artery and the innominate artery have been cleared, a bulldog artery clamp is placed on the vessel near its aortic origin before it is divided and its cut end is brought out underneath the recurrent laryngeal nerve, if the arch is right-sided , both sides of the bulldog clamp should be held by two ligatures tied firmly to prevent any danger of slipping

The subclavian artery is liberated completely from its bed up to its branches , sometimes these branches are given off very low , they are carefully isolated, doubly ligated, and divided An early decision as to the suitability of the subclavian artery for anastomosis must be made, for if it is too short or narrow Potts' operation is substituted Usually the subclavian is divided at the point where the first two vessels are given off after these have been tied and a clamp placed close to the aortic origin of the subclavian artery , at times it is useful to divide the branches after they have left the main trunk and the double-barrelled end so left may have its bridge divided to leave a trumpet-like opening which enables a bigger surface to be sutured to the pulmonary artery ostium

The anastomosis Before this difficult stage of the operation is commenced, the anaesthetist should fully re-inflate the lung for a few minutes to improve the oxygenation of the patient

The apex of the lung is held down by a retractor and the Blalock clamp re-applied to the pulmonary artery as close to the mediastinum as possible Reflux from the two branches of the pulmonary artery is prevented by the use of small bulldog arterial clips or by the use of umbilical tape or by thick silk ligatures placed round the vessels which are each encircled twice the ligatures of course not being tied but held by artery forceps The weight of these acting through the ligatures is sufficient to stop the reflux of blood from the pulmonary end of the vessel after this has been opened The first assistant then approximates the clamp on the pulmonary artery towards the subclavian artery which is held down by traction exerted on the two ligatures already placed around the bulldog clamp

The suture The pulmonary artery is opened by an incision made transversely or in the line of its axis the opening should be a little larger than the open end of the systemic vessel The incision in the pulmonary artery should be well away from the Blalock clamp on its proximal side a stay suture of 00000 special braided silk mounted on a small curved arterial needle is placed at one end of the posterior wall of the future stoma This stay suture is placed by passing the needle first from the outside of the systemic artery at the extreme edge of the posterior wall, and then over to enter the inner side of the corresponding edge of the back wall of the pulmonary artery opening so that when tied the knot will lie outside the vessel this suture is held and not tied A continuous suture is started and passes through the entire thickness of both vessels it is an everting suture which brings intima to intima in contradistinction to the inverting stitch used in the surgery of intestinal anastomosis it commences on the outside of the systemic vessel to reach the lumen of that vessel and is then carried over to the inside of the pulmonary which it then re-enters from the outside so that the loop lies on the adventitia the needle enters the inside of the systemic vessel and is made to re-enter it so that once more the loop lies on the outside the suture is then carried along the posterior wall in this manner taking as small a bite of each vessel as possible until the whole back wall of the anastomosis has been completed No attempt is made to pull the suture taut until the line of sutures has been completed When it has been drawn up taut the first stay suture is tied and one end of it tied to the larger continuous suture A second stay suture is passed at the other end of the back wall and this in turn is tied to the continuous suture to prevent any purse-stringing effect

The anterior wall suture is then completed there are considerable advantages in using interrupted mattress sutures here as this will allow enlargement with normal growth

Before any clamps are loosened firm pressure is maintained on the anastomosis by a small pledglet of gauze on a forceps and this is kept up until the arterial clamps on the distal branches have been removed If at this stage the anastomosis is inspected a little oozing may be seen but need cause little alarm as it ceases usually when the Blalock clamp on the pulmonary artery has been slowly released the distension in the artery being sufficient to tighten the loops of the sutures Occasionally an extra suture may be required to check oozing usually toward the ends of the anastomotic line but there should be no haste in using such sutures as steady pressure with a gauze mop mounted on a forceps will usually stop it When the anastomosis line looks dry the clamp on the systemic artery is released and blood at once pours from it to the pulmonary artery and sets up a characteristic thrill after further insertion if all is well the clamps are removed completely after they have been fully opened

The lung is fully re-inflated by the anaesthetist and the chest closed in layers in the usual way drainage need not be used and the intrapleural pressures are taken and if need be adjusted after the patient has been turned on to his back. (Brock advises drainage

because the ninety-ninth patient in his series developed a serious post-operative eff of considerable size which remained unsuspected.) In my own series the average nu of aspirations required post-operatively has not exceeded one and many of the pa have not required this

Post-operative treatment If the patient has been piloted through to a su ful anastomosis the condition usually improves rapidly and the chief dangers post-operative fall in blood pressure with the attendant risks of cerebral thrombosis in a polycythaemic patient or of clotting in the suture line, and dehydration For this re the intravenous dextrose commenced before operation should be continued until the p is taking fluids really well by mouth Anoxaemia for the first 24 hours is corrected by pl the patient in an oxygen tent, penicillin is continued for at least seven days and doses of Papaveretum or its equivalent are used Gentle physiotherapy is employed 24 hours and the measures employed depend largely on the clinical condition and the logical findings, as a routine a radiograph is taken the day after operation to demon the condition of lung re-expansion and the amount of fluid and air present. Occasio the left lower lobe is collapsed, and if this is so, the child is placed on the right side the left side uppermost, and coughing encouraged in the usual way Fluid and a aspirated if the indications are there

If progress is satisfactory, which is the rule, the patients are allowed out of bed o seventh day and convalescence established.

Vascular anomalies as a cause of technical difficulties Blalock has listed a form list of abnormal arrangements of the vessels usually employed for the anastomosis, may be in the great systemic veins or arteries or in the pulmonary arteries With angiocardiography many of these can be diagnosed before operation One or both pulm arteries may be absent, the whole lung circulation depending on greatly hypertro bronchial vessels, or even from branches derived from the systemic system, such a innominate artery, occasionally the pulmonary artery may be so small that onl division followed by an end-to-end junction with the systemic vessel will enable an lung flow to be established

Gross abnormalities of the vessels arising from the aorta are seen The innom artery may be lacking and four large vessels then arise from the arch, in these circumst a carotid vessel might be selected erroneously instead of the subclavian, with disas disturbance of the cerebral circulation. On occasions the subclavian artery may arise the aorta in the opposite thorax and pass behind the *oesophagus* Minor degre coarctation of aorta may be noted But in most patients subclavian arteries of suffi length and calibre are available for the creation of a good anastomosis.

If the subclavian artery is too short to be approximated except under high te the anastomosis should be an end-to-end one after division of the pulmonary artery Blalock clamp on its proximal end being replaced by a ligature after the division

The indications

The aorta should be a left-sided one for ideal operating conditions in infants severe cyanosis and disability who are not likely to survive to the age when a subcl pulmonary anastomosis could be performed the operation will give better results th subclavian anastomosis Potts believes that in such instances even if the aorta des on the right side an aortic-pulmonary anastomosis should be done When the aor right-sided I have found an anastomosis of the lung end of the divided right pulmo artery to the aorta gives good results and is technically easy to complete

When the subclavian artery is too small or too short this operation should be substituted for subclavian pulmonary anastomosis

Potts operation

Potts (1946) has devised an ingenious clamp consisting of two flanges which when closed around the aorta pinches off an amount of aorta sufficient to allow an anastomosis to be made with the pulmonary artery and yet allows blood to flow through an aorta reduced to approximately half its normal calibre

The operation The pulmonary artery is cleared as in the Blalock operation Potts advises placing thick silk ligatures round the proximal and distal ends of the cleared vessel which is encircled twice so that it is completely but temporarily occluded the descending aorta just distal to the arch is mobilized after an incision has been made through the pleura lateral to it The intercostal arteries in the mobilized section of the aorta are doubly ligated and divided and the clamp applied and slowly tightened After the adventitia over the field of compressed aorta projecting beyond the clamp has been cleared an incision of some 8 mm in length is made into it the sutures encircling the pulmonary artery are then tied to the clamp to approximate the pulmonary artery to the aortic opening the pulmonary artery is then opened and the anastomosis effected (see Fig 17 3)

If the opening is too large there is a danger of pulmonary oedema and of left ventricular hypertrophy developing

Direct relief of the pulmonic obstruction Brock s operation

There can be no doubt that if surgery is indicated for pulmonic stenosis without a ventricular septal defect the only procedure is pulmonary valvotomy as first introduced by Brock. In Fallot s tetralogy direct relief of the obstruction in the right ventricular outflow tract has obvious advantages over indirect procedures as it removes a defect rather than creating another one the artificial ductus and relieves the right ventricular strain

The operation played an important part in the development of the surgery of Fallot s tetralogy most surgeons had difficulties in removing sufficient tissue in those cases (75%) who had infundibular stenosis rather than valvular stenosis the development of open cardiac surgery has shown that major resections of the crista supraventricularis are often necessary and that the outflow track of the right ventricle may require enlargement by suturing in a patch of Ivalon sponge to allow the incision in that part of the ventricle to expand Brock s results in the era before cardio pulmonary by pass was established were so good that they are quoted here

140 CASES

	Very good and good results per cent	Improved per cent	Not Improved per cent	Died per cent
Valvotomy (50)	74	12	2	12
Infundibular resection (62 per cent)	80	7	–	13
Combined infundibular resection and valvotomy	72	21	–	7

These results compared favourably with the results of indirect operations Surgical opinion throughout the world now favours radical cure by open cardiac exposures If there is hypoplasia or atresia of the pulmonary artery if operation has to be done in infants to save life if the poor blood flow to the lung is associated with tricuspid atresia or truncus arteriosus indirect operations will have to be performed Progress and increasing confidence in extra corporeal circulation will enable open cardiac surgery for relief of infundibular

stenosis and the closure of the ventricular septal defect to be done with steadily increasing success

*The direct operations**

Two procedures require discussion, pulmonary valvotomy and resection of infundibular obstructions The former has already been considered on page 407

Infundibular resection or pulmonary valvotomy, if adequate, not only increases the pulmonary blood flow but should lower the pressure in the right ventricle and so decrease the right to left shunt across the septal defect Infundibular obstruction is of several types there may be hypoplasia of the whole outflow tract of the right ventricle so that cavity is connected by a narrow channel, traversing a mass of muscular bands, with the pulmonary artery which will often be small itself such a condition is not suitable for infundibular resection More favourable for direct surgery is the type of obstruction that is severe but placed below the valve area This obstruction may be high in the outflow track (subvalvular) or low or both types may co-exist so that a chamber exists between them During the development of the outflow track a mass of membranous and muscular tissue guards the entrance to the pulmonary artery below its valve, thus the supra-ventricular crest largely disappears except in the situation under consideration where it persists During systole, the anterior wall of the right ventricle closes down on this ridge to obliterate largely the channel leading to a pulmonary valve The greater the ventricular hypertrophy, the more the functional obstruction The condition may be associated with a valvular stenosis (15 per cent to 20 per cent of cases) demanding relief of both obstructions if direct operation is being used This and other abnormalities to be met with are due to errors in the developmental process of the truncus arteriosus (Fig 16 19)

Operative attack on infundibular stenosis

The outflow track of the right ventricle is exposed either deliberately as for pulmonary valvotomy (page 408) (if a definite pre-operative decision has been made to prefer this treatment to that of performing a systemic-pulmonary anastomosis) or as part of the exploration for a patient with the tetralogy through the classical lateral thoracotomy The pericardium is opened widely through an incision in front of the phrenic nerve and the anterior lip is held open by retraction sutures The hypertrophy of the right ventricle will be obvious the state of the pulmonary artery may well decide the procedure to be adopted If it is hypoplastic, atretic or shows a stricture, the decision to proceed with an anastomotic operation may be made If it is really dilated, this usually indicates a pure valvular stenosis especially if the cone of the stenosed valve can be palpated within it valvotomy is then performed

The appearances of infundibular stenosis are

(1) No post-stenotic dilatation of the pulmonary artery

(2) A narrowing of the right ventricle seen best in systole, often indicates the site of stenosis there is often a leash of vessels at this point

(3) There may be an infundibular chamber with a stenosis low down in the outflow track or combined with a high, subvalvular one

(4) The whole outflow track may be very small, often indicating the need for a systemic artery-pulmonary anastomosis instead of a direct attack.

Brock s method of investigating this situation is as follows through a small cardiotomy incision below the suspected site of obstruction a small metal catheter attached to an electro

* These procedures, though obsolete, are described, as they may have occasional application

manometer is introduced so that pressures can be taken in the right ventricle the infundibular stenotic area or chamber and in the pulmonary artery above the valve by this method an accurate estimate of the state of affairs can be obtained if the findings recorded are combined with the results of digital palpation The same manœuvre is repeated after the operative attack on the stenosis For the operative attack the cardiotomy incision is enlarged in a vertical direction the stenosis can be attacked by an incision directly over it or by one below it if the site of stenosis is incised the resecting instruments can be passed upwards and downwards so that a low and high obstruction can be dealt with This incision may be guarded by a purse string suture held in a Rumel s snare but this is not essential Exploration with a sound will help in deciding the site or sites of obstruction which can be removed by Brock s infundibulotome or by special nibbling forceps based on the pattern of pituitary forceps (Bailey Nichols) well described in Bailey s book These instruments are used to bite away parts of the crista supraventricularis and the bands of hypertrophied muscle The procedure is completed by the use of dilating forceps on the stricture area and through the pulmonary valve if this is stenosed The cardiotomy incision is closed by finger pressure for several minutes before a few sutures are placed to close it

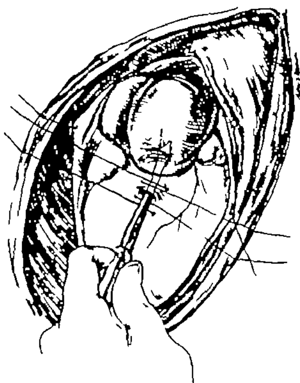


Fig 17 5 —Pulmonary valvotomy by Brock s method. The valvotome has divided the stenosis. Note the typical post-stenotic dilatation of the pulmonary artery

These procedures are now being performed more frequently under direct vision as in other examples of open cardiac surgery In pure valvular stenosis many surgeons are disappointed with the results of blind operations and prefer deliberate exposure under hypothermia (page 408)

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DISEASES OF THE OESOPHAGUS

INTRODUCTION

The oesophagus can be exposed at different sites by a cervico-thoracic transpleural or thoraco abdominal approach in malignant disease the abdomen neck and thorax may require to be opened to allow adequate extirpation so that at the completion of the operation the stomach has been anastomosed to the cervical oesophagus in the neck A similar anastomosis may be required in a few instances of tracheo-oesophageal fistula (see page 435) Because of the lack of a serosal coat and because of the friable nature of the oesophageal muscle all suture lines depend largely on the mucosal layer which if sewn to the stomach jejunum or colon without tension has a remarkably reparative quality It must always be remembered however that this mucosal layer is very adversely affected by the constant presence of gastric juice which produces oesophagitis called reflux by Barrett (1950) and digestion by Peters (1955) operative procedures such as oesophago-gastrostomy or pathological processes such as hiatal hernia can be the cause of such oesophagitis

The oesophagus is well supplied by blood vessels and protected by an excellent upper sphincter the crico pharyngeus and it has a perfect mechanism at its lower end to prevent gastric reflux Although it is subjected to frequent small injuries and certainly affords a passage to pyogenic organisms it rarely develops a primary infection and ulceration is usually secondary to other conditions such as reflux oesophagitis foreign body impaction or rare acquired fistulae The anatomical and physiological dispositions which prevent gastric reflux at the lower end of the oesophagus will be described on page 440

The difficulties of end to-end anastomosis of the divided oesophagus after excision depend entirely on the degree of tension existing under such circumstances apart from the reconstructive operation required for the correction of congenital oesophageal atresia the indications for end to-end repair rarely arise

Oesophagostomy employed occasionally for the removal of an impacted foreign body not recoverable by oesophagoscopy or for the excision of innocent tumours such as leiomyoma, or in the one-stage excision of diverticula is a safe procedure if followed by accurate suture and assisted by chemotherapy The oesophagus heals well after early suture of accidental tears that may follow oesophagoscopy and gastroscopy it is not any intrinsic defect of the oesophagus such as lack of a peritoneal coat or an alleged poverty of blood supply but a persistent leakage of oesophageal contents that leads to mediastinitis Post mortem examination after such a catastrophe following oesophago-gastrostomy or oesophago jejunostomy invariably discloses a healthy viable end of the proximal oesophageal segment and a necrosis of the gastric or jejunal side of the anastomosis the consequence of deficient blood supply or of too much tension Such a leakage is seen most commonly in elderly arterio-sclerotic patients where stomachs have been freely mobilized by division of main vessels to enable a mediastinal oesophago-gastrostomy to be performed the blood supply from a coeliac axis greatly narrowed by pre-existent atheroma may be inadequate after such ligations (Allison 1949) The accident is less likely if the jejunum is employed Increasingly isolated jejunal or colon loops are being used to anastomose the oesophagus to the stomach after excision of non malignant strictures in preference to oesophago jejunostomy which is usually followed by severe nutritional disturbances

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Lymphatics of the oesophagus. Lying in a loose bed of fascia the oesophagus has a rich lymph vessel drainage proceeding to groups of glands at the cardio-oesophageal junction and lesser curvature of the stomach, around the inferior pulmonary veins, both main pulmonary arteries, below the arch of the aorta and on into the cervical lymph gland groups Such lymphatic connections indicate the difficulties of doing a complete block dissection of them during radical oesophageal operations for cancer The close proximity of the thoracic duct is obvious and whenever possible during oesophageal resection its lower end or its tributaries should be tied off when seen In practice, chylothorax after oesophagectomy, though it occurs, is rare

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CHAPTER 18

CONGENITAL ABNORMALITIES OF THE OESOPHAGUS

Atresia

About 4 babies in 10 000 delivered (Franklin 1947) show congenital atresia a far higher incidence than is generally thought * Since the trachea and the oesophagus both develop from the primitive foregut a double abnormality is possible and in practice this is seen In 90 per cent of these abnormalities there is a blind upper oesophageal segment with a gap between it and the lower segment which is in fistulous communication with the back of the lowest portion of the trachea (Fig 18 1) In the next commonest type both upper and lower ends of the oesophagus are blind without any tracheal communication. Very rarely the oesophagus is in open continuity but with a fistulous track into the trachea even more unusual is the communication of both oesophageal segments with the trachea Gross (1953) describes six varieties Of these Group C represented by the first diagram in Fig 18 1

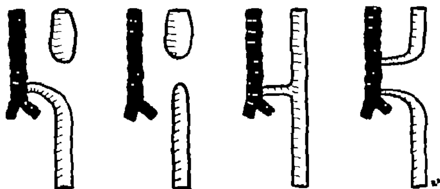


Fig 18·1 —Oesophageal atresia.

The dra ing on the left represents the commonest abnormality present, notably the blind upper pouch and the fistulous communication between the trachea nd the lower segment.

constitutes 90 per cent Roberts (1955) found in material at the Children s Hospital Birmingham that this type can be subdivided into those patients in whom the oesophagus enters the trachea and those when the fistula is much lower and enters the tracheal bifurcation thereby leaving a bigger gap to be bridged at the time of oesophageal anastomosis In this group temporary pharyngostomy and gastrostomy may have to be done

Clinical features and diagnosis There may be no other abnormalities present and the birth weight is usually within normal limits The diagnosis will be made if the association of excessive frothy oral mucus with attacks of cyanosis and choking when feeding is attempted is regarded with deep suspicion the great excess of oral and pharyngeal mucus is a further factor causing dyspnoea These excessive secretions are inhaled by the choking infant and respiratory complications due to infection in collapsed portions of the lung are the cause of death in most infants The abdomen is often distended The diagnosis is confirmed readily by radiology lipiodol (1–2 c c) being instilled after the passage of a soft rubber catheter care should be taken not to allow the spill-over of the opaque oil into the

* At the Children s Hospital Birmingham, we admit 15–20 cases each year Belsey estimates an incidence of 1 in 800 births

chea (Fig 18 3) after films have been taken the lipiodol is aspirated All these measures ould be carried out in the X-ray room

On the straight film the stomach is seen to be distended with air and the tracheo ophageal communication is often clearly made out During the screening and on the dy of the radiographs taken the stomach will be full of air evidence of the presence of stula between the trachea and the distal segment of the oesophagus At the end of the iological survey the oil is aspirated through the catheter. A supply of oxygen must available in the X-ray room during the procedure as severe cyanosis may develop uring aspiration of mucus and oxygen administration

Pre-operative treatment. Obviously oral feeding must be stopped the moment the gnosis has been suspected Early operation is essential to prevent or lessen the risk pulmonary complications from aspiration of pharyngeal secretions or the regurgitation



Fig 18 2



Fig 18 3

Fig 18 2—Radiograph of oesophageal atresia

Correct method sufficient lipiodol has been instilled to outline the upper blind pouch the catheter is in position to aspirate the oil as soon as the photograph has been taken

Fig 18 3

Too much lipiodol has been placed in the dilated upper segment of the oesophagus with the consequence that ... has spilt over into the lungs Type I of oesophageo tracheal fistula with atresia

stomach contents up the lower segment into the trachea But a short time spent on sential pre-operative care is required, pharyngeal secretions are aspirated, cyanosis is rrected by the oxygen tent and frequent changes of position including postural drainage ll help to keep the lungs well aerated and free from secretions Penicillin and streptomycin e given vitamin K is given in a single dose of 2 mg by injection The healthy infant kes scarcely any fluids in the first 24 hours and increasing amounts are swallowed in e next few days if intravenous fluid is given dextrose solution only should be employed ee formula on page 131)

Operative measures Gastrostomy without surgical closure of the tracheo oesophageal fistula allows regurgitation of feeds upwards into the lungs through the tracheal fistula and does not prevent spill-over from the blind upper oesophageal pouch into the trachea

The defects should be corrected at one operation the first essential being the closure of the tracheo-oesophageal fistula, followed by end to-end anastomosis of the oesophageal segments Quite exceptionally the lower end of the gullet may be atretic the only chance of success then lies in mobilizing the stomach and uniting it to the blind upper pouch Gross does this through the right chest alternatively a pharyngostomy and gastrostomy are done after closure of the tracheal fistula. Formal oesophago-gastrostomy or oesophago cologastrostomy is performed later

Anaesthesia General anaesthesia is preferable to local as it allows deliberate surgical manœuvres to be executed in a quiet patient well oxygenated and free from the drawbacks of struggling No premedication is given and a Magill (size 0 or 1) is introduced through a direct laryngoscope through this tube the tracheo-bronchial track is cleared of mucous by suction before induction by ether and oxygen is commenced

A carbon dioxide absorber is introduced into the circuit and as respiration becomes regular they are assisted by manual compression on the anaesthetic bag A high oxygen flow (9–10 litres a minute) is delivered and by hyperventilation the CO_2 is soon washed out so that controlled respiration is established Alternatively small doses of curare may be given

The operation The pleural cavity is opened widely through the fourth right inter space the surfaces being held apart by a small Tuffier type of single rib spreader The anaesthetist should maintain adequate ventilation of the lung at all stages of the operation The lung should be dislocated anteriorly out of the wound

Surgical correction of the deformity In right-sided operations after the exposure is made the azygos vein is isolated, doubly ligated and divided In the common type of deformity the upper segment is readily seen at once The mediastinal pleura over it is incised and the opening so made is continued well down to expose the lower segment which is always far smaller than the upper blind segment in calibre The lower segment communication with the trachea may be quite small great care is necessary when clearing the lower segment so that no unnecessary harm is done to its blood supply The fistula is divided as close to the trachea as possible it is closed with interrupted fine silk sutures (00000) the lower end of the oesophagus is mobilized sufficiently to allow approximation to the upper end Because the upper edge of the lower segment derives its blood supply from the tracheal attachment an avascular area may be present and Belsey recommends excision of the free detached edge until the cut oesophageal wall bleeds freely No clamps are used at any stage because of their traumatic effect on the blood vessels The blind upper end is opened The muscular layer of the lower segment is usually sufficiently developed to allow two layers of suture to be made but reliance is placed chiefly on inter rupted 00000 silk sutures passed through the posterior walls of each side each stitch taking a firm bite of the mucous membranes The sutures are all passed before any are tied When the back walls have been satisfactorily apposed the *anterior* wall of anastomosis is completed all sutures again being passed before any are tied It is essential to use really fine suture material and the suture on an eyeless needle used in the Blalock subclavian pulmonary anastomosis is excellent Penicillin powder is applied to the area and the wound is closed in layers in the usual way The advantages and disadvantages of leaving a closed water-sealed drainage of the pleura or extrapleural space are subject

to the usual differences of opinion. I do not drain these patients as the presence of a tube increases the nursing difficulties in infants. The lung is fully inflated and a radiological examination is carried out two hours later; if there is still a pneumothorax (which is unusual) air is taken off; if the lung is unexpanded in any area the airways are cleared by suction through a fine rubber intratracheal catheter. A polythene tube can be left passing through the anastomosis into the stomach, for feeding purposes. Gross (1953) does a gastrostomy at the end of the operation to allow temporary feeding.

Post-operative treatment. The chief cause of death is respiratory obstruction from the effects of mucus or secretions aspirated into the trachea or bronchi. Until the child is fully recovered from anaesthesia, a head-down position is maintained and careful suction employed; if respiratory distress is notable the trachea is intubated and suction applied. The slightest degree of cyanosis calls for an oxygen tent. Penicillin and streptomycin are continued daily; sedation is provided when needed by sodium phenobarbitone (one-eighth to one-quarter grain) given eight-hourly by intramuscular injection. Routine portable chest radiographs are taken daily to ensure that no hydropneumothorax develops; such always indicate a leak and call for immediate intercostal drainage, the provision of a gastrostomy if not already done and the cessation of oral feeding.

The feeding. Nothing is given by mouth for 4 or 5 days if there is no intra-oesophageal tube, reliance being placed on parenteral fluids. Excess fluid given to infants is highly dangerous as they are easily over-hydrated. In the first week of life the fluid needs are based on the formula of

$$\frac{\textit{age in days}}{7} \times 75 \text{ ml /lb body weight/day.}$$

The fluid given intravenously by Keith's needle is 5 per cent dextrose without saline up to the maximum daily intake. An occasional small blood transfusion (10 ml /lb body weight) is given if anaemia is present. Feeds by mouth are started on the fifth day.

Feeds when a gastrostomy is present. These consist of half-strength breast milk for the first two days, full strength milk being used thereafter. *Oral feeding is started on the tenth day* if a lipiodol swallow shows the anastomosis to be satisfactory. The gastrostomy tube is removed when full oral feeding has been established. *Full details of the feeding programme* are given in Roberts (1955) article quoted at the end of this chapter.

After the immediate 48 hours of post-operative treatment, cough may develop. This indicates (*a*) oedema of the trachea at the site of the closed fistula, (*b*) regurgitation of oro-pharyngeal secretions resulting from oedema at the oesophageal anastomosis site causing a spill over into the lungs which may show areas of atelectasis. The closed fistula may re-open or the oesophageal anastomosis may leak. Careful lipiodol swallows are an invaluable help in disclosing these complications which demand immediate gastrostomy if this has not been done; quite frequently the "leaks" close spontaneously; a large leak indicates the need for thoracotomy and secondary repair. A persistent cough (and this may be seen as late as two years after the primary operation) is usually an indication of a partial recurrence of the oesophago-tracheal fistula. This can be demonstrated by lipiodol swallow. The condition usually requires operative treatment with dissection of fistulous track from much surrounding fibrous tissue and suture of the oesophageal and tracheal ends.

Operative treatment of oesophageal atresia when the lower segment cannot be united to the upper one. If a primary anastomosis of the oesophagus cannot be done because of atresia of the lower segment or because the gap between the two segments is so wide that reunion can only be obtained under severe tension, the stomach may be

mobilized through the right sided approach delivering it through the hiatus and doing a primary oesophago-gastrostomy Usually we prefer to bring the blind upper pouch out into the left side of the neck where it is opened to allow oro pharyngeal secretions to drain away to disconnect any fistula to the trachea and to execute a gastrostomy We have found that in these patients the deglutition actions of the pharynx become seriously impaired if the second operation is delayed too long To overcome this dysfunction of deglutition the infant should be encouraged to swallow normally as soon as possible so that food passes down into the cervical stoma The mother must co-operate in this as fully as possible it is by no means an easy task

At the age of 9 or 10 months normal swallowing is established either by bringing the stomach up through the diaphragm and through the left pleural cavity and anastomosing it to the upper pharyngeal opening in the neck or probably more satisfactorily by using a free colon graft (hinged on the ascending branch of the left colic artery) which after suture to the oesophagostomy in the neck is sutured to the stomach in an iso peristaltic manner to the stomach (See Fig 10 10*b*)

Other congenital abnormalities

True atresia partial or complete may be seen without an oesophago tracheal fistula but is rare

The faulty embryology of this area may explain the formation of mediastinal cysts containing gastric or bronchial elements These mediastinal cysts may be blind without any tracheal or oesophageal opening but a pedicle to the region involved in congenital tracheo-oesophageal fistula may be found (see p 511)

An undoubted example of a double oesophagus has been recorded by Johnstone (1949) The opening of the second oesophagus was from the upper end of the main tube but there was no point of exit as the second one ended blindly One ending at the oesophageal hiatus is illustrated in Fig 18 6

Congenital stricture the gastric lined oesophagus

It is difficult to prove the congenital nature of oesophageal stricture apart from the group just discussed many alleged congenital strictures follow a pre-existent deficiency of the oesophageal hiatal mechanism (short oesophagus oesophagitis hiatal hernia) (Fig 19 9)

The pathology and treatment of this condition is discussed fully in the section under Oesophagitis (page 439) Many writers have written about congenital short oeso phagus it is clear that many of these patients have developed the condition of oesophagitis dependent on a sliding hiatal hernia or an incompetence of the oesophago-gastric junction Barrett (1954) however has shown that a very few patients have a congenitally abnormal oesophagus This diagnosis is reserved for patients in whom the oesophago-gastric junction has never occupied a place below the diaphragm in whom the gullet from the pharynx to the abdomen has the external appearance of a normal oesophagus but is largely lined by columnar epithelium In one infant studied by Barrett at autopsy soon after birth gastric mucosa ex tended from one inch below the cricoid cartilage continuously to the duodenum In the usual short oesophagus in which the cause is a sliding hernia the gastric tissue in the mediastinum is supplied by the left gastric artery whereas in the true congenital example the gastric tissue lining the gullet draws its blood supply from segmental arteries coming off the aorta

If ulcers develop in this type of congenitally short oesophagus they take on the char acteristics of true peptic ulcer of the stomach and they perforate into the pleura aorta or



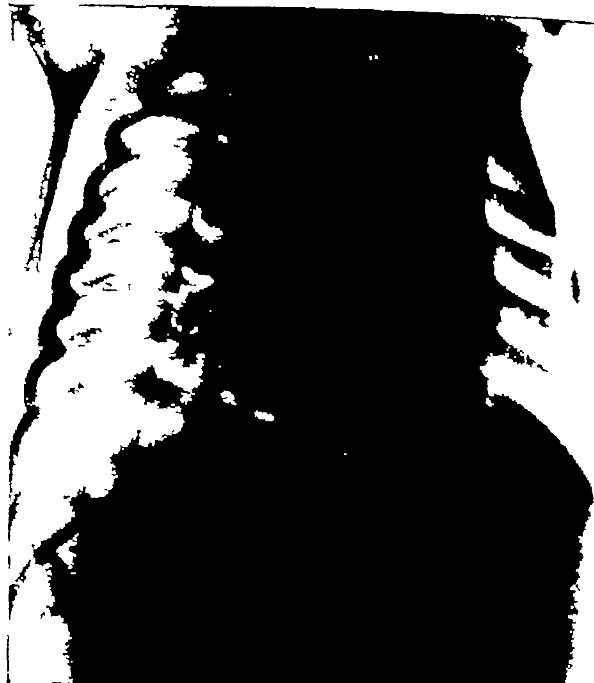


Fig 18 4　　　　Fig 18 5

Fig 18 4 —Oesophagram in a boy of 5 years

He vomited a great deal in the first few weeks of life and had haematemesis after a difficult early life he developed severe dysphagia and could only take fluids The oesophagus is dilated above an area of stricture and spasm there is a typical peptic ulcer crater in the posterior wall of the gullet and a small loculus of stomach is seen above the left leaf of the diaphragm He was treated by oesophagoscopic dilatation and two years later he swallows most foods but has occasional severe bouts of dysphagia and vomiting

Fig 18 5 —A stricture of the oesophagus in a child of 6 weeks

The stricture is secondary to a hiatal deficiency a small portion of stomach is visible above the left leaf of the diaphragm and there is a peptic ulcer just below the area of oesophagus above the stenosed area



(a)



(b)

Fig 18 6 —Duplication cyst of oesophagus

(a) Pre-operative radiograph　　(b) Cyst after excision

Cough from age of 4 weeks vomiting and dyspnoea during and after feeds and loss of weight from six weeks Cyst began at the thoracic inlet blindly being adherent to the oesophagus From the left upper chest it passed beneath the aortic arch into the right lower chest It ended blindly in the oesophageal hiatus Removal (Mr K D Roberts) successfully relieved symptoms As often in this type of case a duplication of the jejunum was present It caused melaena and was also resected successfully

pericardium This complication does not occur in peptic ulcer of the oesophagus due to reflux oesophagitis However peptic ulcers due to sliding hiatal hernia never seem to undergo malignant changes in two of my patients with partially gastric lined oesophagus carcinoma has developed in the gastric mucosal tissue after a long period of years of severe symptoms in the gullet indistinguishable clinically from those of reflux oesophagitis

Congenital partial atresia of the oesophagus

Rarely a partial smooth stenosis in the region of the sixth and seventh thoracic vertebrae just below the tracheal bifurcation may be present since birth these infants have usually had difficulty in swallowing which becomes aggravated when solids are introduced into the diet Dilatation will usually produce relief and sometimes with care these children grow up with only slight dysphagia

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CHAPTER 19

OESOPHAGEAL OBSTRUCTIONS

These may be classified as follows

I *Those due to foreign bodies*

II *Those due to stricture*

(a) Corrosive strictures

(b) The result of reflux oesophagitis and Barrett's ulcer

(c) Gummatous strictures

III *Physiological derangements*

(a) Crico-pharyngeus spasm

(b) Pharyngo-oesophageal diverticula

(c) Diverticula of middle and lower oesophagus

(d) Cardiospasm (Achalasia)

IV *Tumours of the oesophagus*

(a) Innocent

(b) Malignant

V *Acquired tracheo-oesophageal fistulae*

VI *Extra-oesophageal causes*

which are legion and include organic and functional central nervous system conditions, and extrinsic causes from compressing or infiltrating lesions such as carcinoma of the bronchus or aneurysms

FOREIGN BODIES IN THE OESOPHAGUS

All impacted foreign bodies in the oesophagus are not radio-opaque In practice many patients are convinced that something has " stuck in the throat " , since in most instances this is not so, there is a danger that genuine impaction may be overlooked If suspicion exists and a radiograph is negative a barium swallow is of great value if the material impacted is not radio-opaque, for the oesophagus in the area of the arrested foreign body will normally show a segment of hesitant, spastic oesophagus If such is detected, oesophagoscopy should be done without delay as the dangers of perforation with subsequent mediastinitis are severe Metallic foreign bodies detected in the oesophagus should be removed at once and it is foolish to wait in the hope that they will pass on into the stomach , many would do so undoubtedly, but the hazards attending those that do not should not be accepted Occasional indications for a direct transpleural exposure of the oesophagus exist , if the foreign body has been impacted for a long period oesophagoscopic removal may be dangerous and if difficulty is experienced at the endoscopic examination the foreign body, which may be a razor-blade (Sellors, 1947), should be removed through a deliberate oesophagostomy, the opening being closed in two or three layers

STRICTURE OF THE OESOPHAGUS

Acquired strictures are due to the sequels of oesophagitis to trauma the swallowing of corrosive fluids and very rarely to gummatous infiltration In Britain the commonest cause is stricture formation due to reflux oesophagitis

Corrosive strictures

Accidental or deliberate swallowing of strong acids or alkalis may result in immediate death but in the survivors stricture is common As the crico-pharyngeus opens widely with the act of swallowing the worst areas of strictures are usually below this level and affect the true oesophagus usually below the aortic arch There is often a time interval of weeks before symptoms of stricture develop In the treatment of these obstructions gentle dilatation at first under direct oesophagoscopic vision, is pre-eminently the method of choice and it is unusual not to obtain good results Exceptionally the treatment has to proceed along the lines of retrograde dilatation a gastrostomy is done to relieve the effects of starvation later the patient is encouraged to swallow a strong thread which usually protrudes through the gastrostomy This is attached to a first size of dilating bougie which may have to be a ureteric catheter at first and gentle traction on the thread through the mouth is executed by the patient himself gradually larger and larger bougies will pass and the patient then performs the dilatations himself by passing them through the mouth Grey Turner (1940) has constantly drawn attention to the value of this treatment



FIG 19-1 —Corrosive stricture of oesophagus.

This responded completely to gradual dilatation and the patient three years later ca ss flow y type of food.

Only after failure has attended the most persistent attempts at dilatations should operations such as oesophago-gastrostomy or the inlay of a jejunal or colic loop be considered *

Oesophagitis peptic ulcer stricture

Allison (1948) clarified the pathological course of oesophagitis peptic ulcer and stricture formation and showed that in the overwhelming majority of patients the exciting cause of these lesions lies in the presence of a sliding hiatal hernia which allows gastric juice to flow into the gullet The digestive action of gastric juice on the oesophagus is well established this action may proceed even when acid is absent and Aylwin (1953) believes the pepsin is probably the most important agent digestion oesophagitis may follow the regurgitation of duodenal or jejunal contents following oesophago-duodenostomy It has been ascribed to trauma resulting from the presence of an in-dwelling duodenal tube but this again is probably due to the reflux of gastric juice around such a tube In some patients with hiatal

* A careful description of 153 cases of caustic stricture of the oesophagus is given by Marchand (1955) it is a rare condition in Britain as lye is not readily available

insufficiency the oesophagitis is followed by peptic ulceration of the oesophagus which in the process of healing leads to a stricture of the gullet accompanied by sever spasm. A true gastric ulcer in the herniated part of the stomach or of a gastric-lined oesophagus may be present either alone or with a peptic oesophageal ulcer. In reflux oesophagitis if ulcer exists it is always in squamous epithelium (Allison's ulcer). An ulcer developing in a gastric-lined oesophagus is quite different and as suggested by Allison should be called "Barrett's ulcer".

The oesophago-gastric barrier

In the normal individual, gastric reflux, even in the head down position, is completely prevented by a highly efficient mechanism, the exact nature of which is perplexing though certain facts are clear and opinion is slowly crystallizing as follows. (*a*) The oesophageal hiatus is surrounded by the right crus which on inspiration contracts and pulls down the



Fig. 19.2



Fig. 19.3

Fig. 19.2.—Peptic ulcer of the oesophagus and stricture of the lower end of the oesophagus shown by a barium meal in a man of 62 with an hiatal hernia.

(Radiograph by courtesy of Dr. W. F. Hudson of Banbury.)

Fig. 19.3.—Oesophageal stricture in a man of 46 years. Severe dysphagia of a year's duration followed a long history of dyspepsia.

The appearance of a defective filling just above the stricture was due to an impacted damson stone. This was removed at oesophagoscopy and the stricture dilated. Biopsy of tissue just beyond the limit of stricture revealed gastric mucosa, thus confirming the radiological evidence of gastric herniation with typical mucosal pattern.

lower end of the oesophagus just before its entrance into the stomach so that the oesophago gastric angle becomes more acute (Allison 1951) (*b*) The phreno-oesophageal ligaments consisting of peritoneum fibrous and elastic tissue are attached to the region of the oesophago-gastric junction and become taut during inspiration (*c*) The circular muscle fibres at the lower end of the oesophagus play no real part in preventing gastric reflux as the complete division in Heller s operation for the relief of cardiospasm is not followed by regurgitation (*d*) During inspiration the intra-oesophageal pressure drops and the abdominal pressure rises In spite of this pressure difference (measured by Dornhorst (1954) as 15 mm Hg rising to 80 mm Hg during an inspiratory effort against a closed glottis) no regurgitant flow follows (*e*) The area of the functional cardia is sharply localized and is provided by a valve formed by the action of the muscularis mucosae on the mucosa (Dornhorst 1954) (*f*) The mechanism which prevents regurgitation is grossly disturbed and made ineffective when a sliding hiatal hernia develops (*g*) Belsey (1955) has shown by barium meal studies that after bilateral phrenicectomy (which must paralyse the whole of the right crus which receives a nerve supply only from the phrenic nerves as proved by Leigh Collis (1954)) there is no gastric reflux into the oesophagus

More controversial are the points raised by Barrett (1954) who believes the length of the left gastric artery may play a part in deciding whether a sliding hernia develops or not and that some gastric muscle fibres loop around the cardiac incision and help to maintain its obliquity the sling lies beneath the mucous membrane and passes from the lesser curve posteriorly around the oesophago-gastric junction and back on to the front of the stomach.

Hiatal deficiency as a cause of oesophageal ulcer and stricture

Oesophageal hiatus deficiency is seen in infants and adults The pathological effects in both groups are the same surface ulceration of the oesophageal mucous membrane may be followed by a typical peptic ulcer and fibrosis and spasm follows here as in the pylorus when a gastric or duodenal ulcer is present (see Fig 19 2)

This condition of oesophagitis ascending fibrosis (Kelly 1930) peptic ulceration and shortening of the oesophagus all due to hiatal deficiency undoubtedly explains most instances of oesophagitis But Barrett (1954) has been careful to indicate an important but less common type of patient in this group there is a congenital gastric lined oesophagus in which a real gastric ulcer may arise Allison and Johnstone (1953) have described this in detail and call it the oesophagus lined with gastric mucous membrane Ulcers in such a gullet cause obstruction ten times less frequently than does ulceration of true oesophageal mucous membrane Both states may co-exist Diagnosis requires radiology and oesophago scopy Barrett now uses the term columnar epithelium instead of gastric mucosa

Clinical features of peptic ulcer of the oesophagus oesophagitis and oesophageal stricture Since Allison drew attention to these patients they are seen in increasing numbers in thoracic clinics It is most important to recognize them and each year patients are seen who have been diagnosed as suffering from carcinoma of the oesophagus others have been referred as tuberculous or gummatous strictures fuller investigation reveals a group of treatable patients with a good prognosis

Although hiatal deficiency is the cause of the condition all patients with gastric herniation into the posterior mediastinum do not develop oesophagitis and its sequelae just as all patients who have undergone gastro-enterostomy do not suffer from subsequent gastro jejunal ulceration But the constant reflux of gastric juice into the oesophagus in certain patients especially those with hyperchlorhydria causes oesophagitis These patients usually have a long history of upper abdominal dyspepsia often suggestive of cholecystitis

or peptic ulcer, which gradually gives way to a story of increasing dysphagia which is not necessarily progressive, there being notable remissions The pain, which has been a long-standing complaint, often disappears with the advent of dysphagia as happens so often in pyloric stenosis, the result of a pyloric peptic ulcer of long duration But the formation of a peptic ulcer in the oesophagus causes heartburn and pain situated behind the sternum and usually in the back in the area of the eighth dorsal vertebra Vomiting, the result of oesophageal regurgitation, is a constant and distressing feature and weight loss may be severe Regurgitation is often induced by bending down in the act of tying shoe-laces or gardening Anaemia is sometimes severe

The radiological appearances may show a stricture only, without sign of an ulcer crater, and there is a gastric hernia with a typical stomach mucosal pattern evident If the ulceration has subsided to be replaced by a healing fibrosis the appearances of stricture are the predominant feature It is important to remember that part of the stricture appearance is due to spasm at oesophagoscopy in these patients after a preliminary dilatation it is exceptional not to be able to pass the instrument right through into the stomach

Oesophagoscopic appearances. It is unsafe to diagnose this condition on radiological appearances alone and the patients must be examined with the oesophagoscope this is safely and easily carried out under local anaesthesia as an out-patient procedure The gullet above the affected area is dilated and contains typical frothy moist contents The appearances of oesophagitis vary from congestion and oedema to violent crimson red colouration indicative of extreme inflammatory hyperaemia when severe congestion is present the surface bleeds readily In some areas patches of leucoplakia vary with surface and deep ulceration The appearances mentioned are rarely evident in that part of the gullet above the level of the aortic arch If there is no stenosis the oesophagoscope can be passed on into the stomach which can be entered without any manœuvre being necessary to negotiate the gastro-oesophageal junction which is normally placed obliquely to the left, in these patients the oesophagus enters the stomach in a direct line of continuity The area of the cardia may not be easy to define as the instrument reaches the stomach at a level higher than the normal 40–42 cm. from the upper incisor teeth Biopsy specimens are important, peptic ulceration due to reflux is always in oesophageal mucous membrane whereas in Barrett's ulcer the tissue will be gastric in type The reader will find these points well discussed in the papers by Allison (1953) and Barrett (1954, 1957), references to which are given at the end of this chapter



FIG 19 4 —The mucosal folds at the cardia sometimes closely resemble the mitral valve, and in this 71-year-old female its apposition during sudden rises in intra gastric pressure, is probably one of the main features preventing reflux into the oesophagus

(Preparation by G S M Botha, F R C S)

When stenosis and ulceration are present the oesophagus above the constricted area shows the appearances of chronic oesophagitis but the ulcer which usually lies just distal to the start of the stricture is not easily seen though the presence of polypoid and granulation tissue suggests one is there

The stricture responds to gentle dilatation and once this has been done fluid wells up from the stomach

Oesophago-gastrostomy as a cause of oesophagitis and its sequelae The sphincteric mechanism is destroyed when the oesophagus is resected for malignant disease and the upper end of the gullet is anastomosed to the stomach after it has been mobilized and brought up into the thorax. This operation and the oesophago-gastrostomy that used to be performed for the relief of cardiospasm is usually followed by oesophagitis and peptic ulceration This hazard can be avoided in resection of the lower end of the oesophagus



FIG 19-5—Barium swallow in a woman after oesophago-gastrostomy following excision of the low third of the gullet for carcinoma.

Dysphagia nine months later was due to oesophagitis and ulceration as confirmed by oesophagoscopic examination.

for cancer or stricture by joining the gullet via an isolated jejunal or colon loop to stomach or by oesophago jejunostomy but for high oesophageal *resections* the sto can be mobilized and placed high in the chest and the risk of later oesophagitis be t There *is no* need however to employ the operation of oesophago-gastrostomy in any p with cardiospasm as better results follow the cardiomyotomy *operation* of Heller p 464) which leaves the hiatal mechanism of the lower end of the oesophagus i The careful follow up of Barret and Franklin (1949) on patients who have been sub to oesophago-gastrostomy for cardiospasm leaves *no* room for doubting the high in of serious oesophagitis that follows the procedure

Treatment of oesophagitis due to hiatal hernia The repair of the hernia ulceration and stricture formation has developed is the logical course A word of ca

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FIG 10-5 —Barium swallow in a woman after oesophago-gastrostomy following excision of the lower third of the gullet for carcinoma.
Dysphagia nine months later was due to oesophagitis and ulceration as confirmed by oesophagoscopic examination

for cancer or stricture by joining the gullet via an isolated jejunal or colon loop to the stomach or by oesophago jejunostomy but for high oesophageal resections the stomach can be mobilized and placed high in the chest and the risk of later oesophagitis be taken. There is no need, however to employ the operation of oesophago-gastrostomy in any patient with cardiospasm as better results follow the cardiomyotomy operation of Heller (see p 464) which leaves the hiatal mechanism of the lower end of the oesophagus intact The careful follow up of Barret and Franklin (1949) on patients who have been subjected to oesophago-gastrostomy for cardiospasm leaves no room for doubting the high incidence of serious oesophagitis that follows the procedure

Treatment of oesophagitis due to hiatal hernia The repair of the hernia before ulceration and stricture formation has developed is the logical course A word of caution

however, must be given about advising surgery in infants as the results of operation are disappointing and most of them show remarkable recovery of the oesophageal lesion if they are treated by persistent propping up and the use of thickened feeds (Fig 26 13) Surgeons contemplating surgical repair of hiatal hernia in infants should read the paper of Carré, Astley and Smellie published on the material studied at the Children's Hospital, Birmingham 112 infants and children with partial thoracic stomach have been followed-up for several years Most are now symptomless and about 7 per cent have evidence of gastric reflux and stricture of varying degrees (see Chapter 26)

If the stricture is long, the result of ulceration and fibrosis, the replacement of the stomach into the abdomen is not possible , if the symptoms are those of heartburn, indigestion and pain, alkalis, dietetic measures, relief from anxiety and periods of bed rest help Correction of the mechanical aspect of the problem is sought by making the patient sleep in the upright position, so that less gastric regurgitation will follow than in the lying-down state

If dysphagia results from stenosis, oesophagoscopic dilatations, which may have to be repeated at intervals are used in addition to the medical measures It must always be remembered that the relief of the obstructive state may well be followed by increase in gastric regurgitation and, especially in children, severe vomiting may follow as the result of an immediate post-operative exacerbation of the oesophagitis above the site of the dilated stricture When this unhappy result follows successful dilatation major surgery may be necessary *

Major surgery for non-malignant stricture of the oesophagus. Patients with long-standing dysphagia become astonishingly tolerant to their condition and hide their real discomfort to an extraordinary extent and this is seen in stricture as well as in cardiospasm Severe nutritional changes develop and emaciation may become extreme with all the classical associated features of malnutrition, hypovitaminosis, anaemia and severe neurological disorders such as peripheral neuritis and beri-beri In children growth may cease and juvenilism become present with dwarfism, amenorrhoea and general mental backwardness

The relief of stricture following oesophagitis is not easy at all costs permanent gastrostomy must be avoided The following operations are available

I Oesophago-gastrostomy (with or without partial gastrectomy)

II Oesophago-jejunostomy

III Oesophago-jejuno-gastrostomy (Brain) or oesophago-colo-gastrostomy

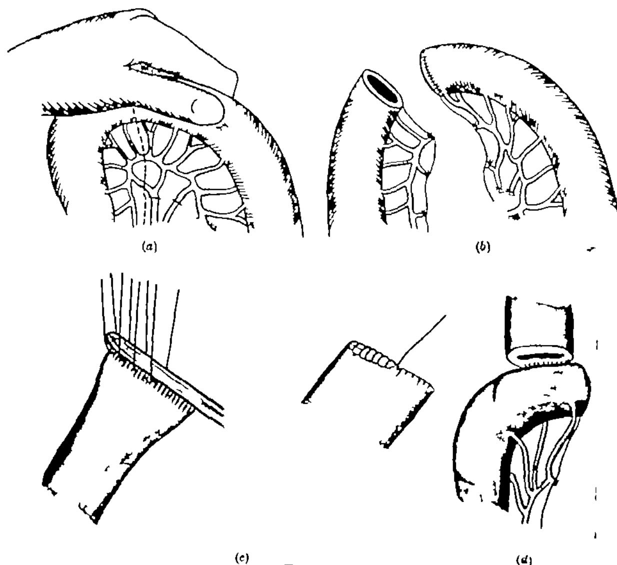
These procedures have replaced the use of pre-sternal anastomosis in which skin and jejunal tubes were used as these procedures usually have to be performed in stages and are technically difficult Of them all, I believe the procedure advocated by Brain (1950) in which an isolated jejunal loop is used to replace the gap left by excision of the stenosed oesophageal segment is the best Unfortunately in children this is rarely possible as a sufficiently long loop cannot be fashioned Oesophago-jejunostomy has the grave drawback that the stomach is excluded from the normal route taken by the swallowed food and is often associated with grave nutritional defects following diarrhoea, steatorrhoea and anorexia These patients often become emaciated and exhausted Oesophago-gastrostomy carries the risk of producing reflux oesophagitis In practice, however, it may be surprisingly successful if the anastomosis is done just below the aortic arch as oesophagitis in the gullet above this level is not very common Belsey does this operation with great success in

* Wangensteen has had some good results in this type of case by combining partial gastrectomy (to diminish gastric secretion) with dilatations

children but at the same time removes the lesser curve of the stomach to diminish the risk of oesophagitis from gastric secretions The nutritional state of his patients (I have seen several some years after their operation) is excellent and they have developed normally I have had the same experience without doing partial gastrectomy in a few patients

The use of an isolated colon loop hinged on the ascending branch of the left colic artery is proving satisfactory and is being used more and more in my own practice and in that of my colleagues Long viable loops can be provided and can be brought up even into the neck either behind the sternum or through the left pleural cavity (see Fig 19 10)

The operation of oesophago-jejunostomy or oesophago-jejuno-gastrostomy With the patient in the true lateral thoracic position the chest and abdomen are



(a) (b) (c) (d)

Fig 19-6

(a) and (b) Diagram illustrating steps in the preparation of a jejunal loop
(c) Closure of the open end of the jejunal loop which will be employed for oesophago-jejunostomy
(d) First stage of the anastomosis of the oesophagus to the jejunum.

opened widely through a thoraco laparotomy incision with complete excision of the left eighth rib and its cartilage the pleural cavity is opened and the diaphragm divided down to the oesophageal hiatus as in the operation for lower oesophagectomy or total gastrectomy (see p 470)

The jejunal loop is prepared before the oesophagus is mobilized A Roux loop is

employed The site of section of the jejunum is carefully made and this should be some 10 inches from the duodeno-jejunal junction To preserve a good supply to the jejunal loop the primary trunks of the jejunal vessels are isolated and divided proximal to the first arch and three of these vessels can usually be divided with safety but the vascularity of the loop must be tested before the actual division this can be assessed by digital compression of the vessel before ligation The mesentery is then incised up to the selected point of intestinal section and the vascular arcade near to the bowel is divided A sufficient



(a) (b) (c)

FIG 19 7—Radiographs of a woman of 64 years

There was a long history of dyspepsia for 10 years In January 1950 (Fig 19 8 (a)) the symptoms were those of regurgitation with pain in the upper chest and back Nine months later severe dysphagia had developed and the radiographic appearances had changed to one of stricture in addition to hiatal hernia (Fig 19 8 (b)) The stricture was dilated but caused severe post operative pain of a burning character associated with constant regurgitation of food and gastric juice she lost weight rapidly The medical regime was abandoned and oesophago jejunostomy was done with relief of dysphagia (Fig 19 8 (c)) She has some nutritional defects five years later

length of jejunum is essential to avoid tension on its vessels when it is placed in the mediastinum The cut end of the loop is then closed with two layers of suture, one through the mucosa and one to invert the serous coat this loop is then passed through a hole in the transverse mesocolon as near to the splenic flexure as possible and is led on through the lesser sac into the posterior mediastinum

The oesophagus is then mobilized this may be difficult because of peri-oesophageal adhesions and there are usually many vascular matted lymphatic glands in the region of the stricture and ulcer After the oesophagus has been thoroughly freed and cleared it is divided at its junction with the stomach between a pair of Schumacher's clamps the gastric end being closed with two layers of sutures An incision is then made into the anti-mesenteric border of the delivered jejunal loop without the use of clamps which may damage the impoverished blood supply. the opening should correspond with the size of the oesophageal lumen above the stricture Two stay sutures are then inserted into the medial lateral edge of the oesophagus just above the point selected for the section The stenosed area of the oesophagus is then cut away and a series of interrupted sutures applied to the



(a)



(b)



(c)

Fig 19·8

(a) Barium swallow in a child of 8 years with dysphagia all her life

(b) After oesophago-jejunostomy: this child swallowed normally but at the age of 14 she was small and would not eat properly because of complete lack of appetite especially for meat: she was anaemic and had diarrhoea.

(c) Radiograph taken after the jejunum had been divided and the upper end anastomosed to the stomach, followed by end to-end anastomosis of the divided jejunum Within a month of this, appetite was restored and diarrhoea ceased Six months later she had put on a stone and a half and was a normal child at full school



(*a*)

FIG 199—Boy aged 4 years Dysphagia since birth after haematemesis and vomiting, he was nurtured entirely on fluids

The upper third of the oesophagus is dilated above the strictured area which leads to the thoracically placed portion of stomach

(*a*) The stricture was easily dilated but this was followed by persistent vomiting and great loss of weight A high oesophago gastrostomy was performed with the anastomosis just below the aortic arch, recovery was uneventful For the last five years there have been no symptoms and considerable weight gain

(*b*) Straight radiograph showing high thoracic portion of the stomach This boy s sister, now aged 2 years, has the same condition—

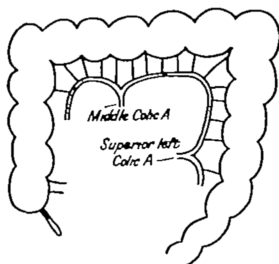
(*c*) and has been successfully treated by the same operation

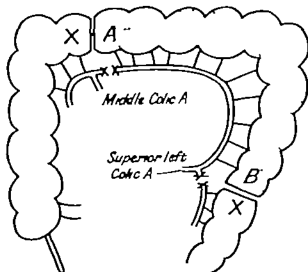


(*b*)

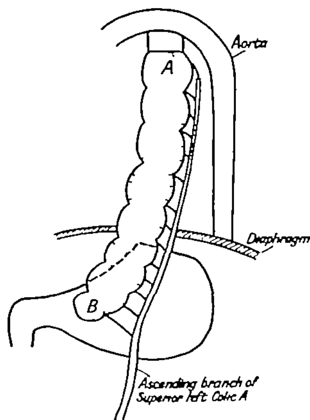


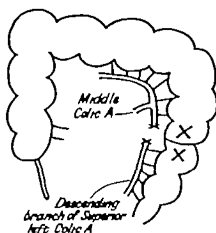
(*c*)





(a)





(b)

Fig 10-10 (a)

(1) Normal vascular anatomy of the colon

Preparation of the graft depends on the presence of the anastomotic arterial arcade between the middle and superior left colic arteries

(2) The colon divided

Left branch of middle colic artery and descending branch of superior left colic artery ligated and divided. Colon continuity restored by anastomosing X — X. This leaves the graft AB supplied by the ascending branch of the superior left colic artery

Fig 10-10 (b) —The completed operation

The proximal end of the graft "A" is anastomosed to the oesophagus, the distal end "B" to the stomach, that is the graft functions in an isoperistaltic way. Anastomosis B is made obliquely low down on the lesser curvature to diminish reflux. The colon at X—X is supplied by the right branch of the middle colic artery and by the descending branch of the superior left colic artery anastomosing with the inferior left colic arteries.

fascia propria and muscle of the posterior wall of the oesophagus and passed through the sero-muscular coat of the jejunum These sutures are tied and are followed by a further series of interrupted thread or silk sutures through all coats of the posterior wall of the oesophagus and that of the jejunal stoma None of these are tied until all have been passed When this has been done there should be no suggestion of any tension

The mucous membranes of the anterior wall are then united by interrupted sutures and reinforced by a second layer through the oesophageal muscle and the jejunal mucosa The area of anastomosis is then fixed by a few interrupted sutures to the parietal pleura and a flap of pleura lifted from the chest wall may be wrapped around it The proximal end of the divided jejunum is then sutured to an opening made into the side of the jejunum below the anastomosis to complete the Roux-en-Y

The abdomen, diaphragm and chest wall are closed in the usual way with a water-sealed drain left in the pleural cavity

Oesophago-jejuno-gastrostomy. Because of the adverse nutritional and metabolic effects that often follow exclusion of the stomach by oesophago-jejunostomy Brain (1953) for the first time as far as I know, used an isolated jejunal loop with a meticulously preserved blood supply to join up the oesophagus to the stomach When this is technically possible, the results are excellent The steps are those described in the previous section for oesophago-jejunostomy except that a free jejunal loop is fashioned followed by end-to-end anastomosis of the divided distal jejunum after the oesophago-jejuno-gastric anastomosis has been performed If the jejunal mesentery is too short the transverse colon can be used as described by Moroney (1953)



Fig 19 10 (c) —Radiograph after the operation of oesophago colo-gastrostomy performed for stricture due to reflux oesophagitis

If an oesophago-jejunostomy has been performed and the alimentary sequelae are bad it is a simple matter to implant the jejunum into the stomach without disturbing its junction with the previously excised oesophagus and to restore the alimentary course back to normal This has been done in the patient whose radiographs are presented in Fig 19 8 (c), with immediate and persistent relief of symptoms of anorexia and steatorrhoea

Oesophago-colo-gastrostomy. The important pre-operative measure is the use of streptomycin and a non-absorbable sulpha preparation for adequate colon sterilization A large colon graft can be obtained with its blood supply coming from the left colic artery followed by the restoration of the colon by end-to-end anastomosis This can be done through an extended thoraco-laparotomy incision if the loop is being used for a stricture of the lower end of the oesophagus If the loop is required to be brought up into the neck, e g for the second stage of an operation for tracheo-oesophageal fistula (see page 435) the mobilization is done through a laparotomy incision A transverse incision is then made above the sternum and working from above and below the loose tissue behind the sternum is cleared and the loop brought up into the neck so that it can be anastomosed to the cervical oesophagus in an iso-peristaltic manner

PHYSIOLOGICAL DERANGEMENTS OF THE OESOPHAGUS

No patient with dysphagia should be labelled as functional or spasm until full investigations have been carried out in any clinic dealing with dysphagic patients many suffer from nervous functional disorders and a few from serious organic disease of the central nervous system The true neurotic almost invariably complains that the difficulty is in the lower portion of the pharynx and rarely in the true oesophagus in addition to the difficulty in swallowing there is often a complaint of suffocation the whole story being detailed with a wealth of dramatic detail usually absent from the matter-of fact history given by the patient with organic obstruction but in spite of the lurid story a clinical examination of the thyroid gland, the whole neck and an endoscopic view of the pharynx and larynx provide negative results and a barium meal swallow shows no obstruction and no deviation from the normal act of deglutition. If a full neurological examination shows no organic abnormality a diagnosis of globus hystericus can be made and the patient should be treated psychologically

Disorders in the co-ordination of the oesophageal muscles not infrequently exist and whatever their etiology they produce anatomical variations that are readily demonstrated especially by radiology The deviations include hypertrophy or dilatation or spasm over large areas alternation of dilatation and contraction persistent contraction of the circular muscular fibres at the upper or lower end of the oesophagus and diverticulum formation

The act of swallowing When the bolus of food is driven forcibly by the contractions of the pharyngeal muscle into the upper end of the oesophagus a strong wave of peristalsis is initiated and passes down to the oesophago-gastric junction this is the *primary wave* of Templeton (1944) and depends for its integrity on a precise relaxation of the crico pharyngeus muscle just before the food reaches it similarly the circular muscle of the lower two inches of the oesophagus relaxes if the peristaltic wave is to force the bolus on into the stomach If either of these sphincters fails to relax well recognized pathological conditions such as the upper dysphagia of the Patterson Brown Kelly or Plummer Vinson syndrome or the lower obstruction of cardiospasm may develop As discussed later this faulty relaxation may well play a part in diverticulum formation When the lower end of the oesophagus is obstructed by growth the peristaltic wave is often abnormal just as it is in early examples of cardiospasm

This major primary peristaltic wave is supplemented or replaced in certain patho logical conditions by secondary and tertiary waves The secondary waves best seen in cases of obstruction (Johnstone 1949) start at the level of the aortic arch. The tertiary waves are irregular segmental contractions noted in the lowest third of the oesophagus where unstriped muscle fibres alone exist The physiological significance of these con tractions is imperfectly understood but they can be produced by abnormal stimuli such as inflation of a balloon placed in this oesophageal segment They are seen in patients without any dysphagia especially in the elderly during routine barium meal examinations but occasionally in patients with irregular attacks of difficulty in swallowing but in whom oesophagoscopy reveals no abnormality except perhaps enlarged mucous membrane folds Allison and Johnstone have noted them in the early stages of cardiospasm Their occurrence may be responsible for the condition known as corkscrew oesophagus In Fig 19 12 in addition to the corkscrew appearance with apparent false diverticula the presence of a true diverticulum of the mid thoracic oesophagus will be noted and this radiograph supports

fascia propria and muscle of the posterior wall of the oesophagus and passed through the sero-muscular coat of the jejunum these sutures are tied and are followed by a further series of interrupted thread or silk sutures through all coats of the posterior wall of the oesophagus and that of the jejunal stoma None of these are tied *until* all have been passed When this has been done there should be no suggestion of any tension

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the view that pulsion diverticula are often associated with faulty muscular contrac (see pharyngo-oesophageal diverticula, below)

Quite exceptionally a simple spasm of the lower third of the oesophagus is noted condition must not be diagnosed as such on the results of a barium oesophageal picture oesophagoscopy should be done to exclude a more serious lesion A series of ba examinations will usually show that at different times the segments affected by the sp



FIG 19 11 FIG 19 12

FIG. 19 11 —At screening, most irregular contractions of the oesophagus were noted with an apparent area of persistent spasm in the mid-oesophagus as shown in this radiograph

Oesophagoscopy revealed a carcinoma of the stomach including the lower end of the oesophagus

FIG 19 12 —Corkscrew oesophagus in a patient with a mid thoracic diverticulum

Quite exceptionally this condition may cause severe dysphagia relief will follow division of the muscle down to mucosa over the last two inches of the oesophagus

alter but the condition as far as I know is only seen in the lower portion of the oesophag which has unstriped muscle in its wall This type of spasm may be present when the is a serious abdominal lesion and is seen even in very young infants

The Patterson-Brown-Kelly or Plummer-Vinson syndrome

It seems unfair to classify this disease as hysterical or functional, for the patient who are invariably women, have all the signs and symptoms of hypochromic anaemia possibly the deficient iron intake is secondary to a hysterical dysphagia but the patien when seen have organic disease affecting the mucous membrane of the lips, which ofte show cracks at the edges of the tongue which is small, smooth and red, and of the pharyng

mucosa The crico-pharyngeus muscle is in tight spasm but with care an oesophagoscope under local anaesthesia can be passed The blood picture is typical with a haemoglobin that may be below 30 per cent there is frequently an achlorhydria and the spleen is usually palpable If unrelieved the condition may pass on into a post-cricoid carcinoma

Treatment This is essentially by a full long-continued course of iron therapy preceded by a single oesophagoscopic examination the passage of the oesophagoscope is sufficient to dilate the crico pharyngeus and oesophagoscopy also enables any suspicion of the development of a post-cricoid carcinoma to be confirmed or dispelled

Pharyngo-oesophageal diverticulum

The mouth of the sac invariably lies in the weak area of the posterior wall of the pharyngo-oesophageal junction between the oblique fibres of the inferior constrictor muscle of the pharynx and the transversely placed crico pharyngeus muscle at the start of the oesophagus The wall of the diverticulum consists largely of mucous membrane but contains muscle fibres once the sac begins to bulge it tends to enlarge towards the left side of the neck possibly because there is more space between the oesophagus and the carotid artery on the left than on the right subsequent to this left-sided protrusion the diverticulum may come to lie behind the upper part of the oesophagus and descend well into the thoracic inlet

Etiology The condition is almost unknown in the young and is usually present well after middle age and more commonly in males The diverticulum is probably the result of pulsion forces and at operation the fundus of the sac is notably free from adhesion to surrounding structures so that a traction element can hardly be involved indeed the smooth outline of the fundus is in complete contrast to the spiky apex of the rare traction diverticulum seen in the thoracic oesophagus If there is a considerable and progressive area of weakness in Killian s triangle the high intrapharyngeal pressure will tend to drive the mucous membrane out beyond the wall of the pharynx If the crico-pharyngeus muscle is slow to relax the effect of this pressure will be accentuated and Johnstone has noted in the early stage of diverticulum formation that there is a slight hesitation before the barium enters the oesophagus this may well be due to slow relaxation of the crico-pharyngeus muscle possibly the result of inco-ordination Negus (1950) has reported his conviction based on accurate observation that slight dysphagia precedes the diverticulum formation The weak area described is present in all humans but only a few develop pouches which follow faulty co-ordination of deglutition muscles in which the crico-pharyngeus is chiefly concerned. This disordered mechanism may be due to chronic hypopharyngitis and fibrosis It is certain that a small diverticulum as shown in Figs 19 13 19 14 cannot be the cause of the slight dysphagia present but is indeed the result of it If dysphagia is present with such a small diverticulum the surgical duty involves an inspection and dilatation of the crico-pharyngeus equally important in the patient with a large diverticulum is such an examination and dilatation in addition to the excision of the sac

The weakness of the area between the inferior constrictor muscle and the oesophagus may be due to a constant attrition of this area against the cervical vertebral column especially in patients with spinal osteo-arthritis. The higher male incidence may be due to the larger larynx and the increased friction of this area of the pharyngeal wall against the vertebral column during deglutition

Symptoms The sufferer is usually elderly and has had symptoms for two to three years often after years of minor dysphagia These symptoms may be quite bizarre though of them all, progressive dysphagia is the commonest The patients locate the difficulty in

swallowing just above the sternum and many describe an intermittent obstruction which can be cleared by odd contractions of the muscles of the neck associated with peculiar grimaces The sac itself may become full of retained food and sometimes swallowing cannot be achieved until the sac is full, or the patient presses with his hand on the lower pharynx during the course of the meal Regurgitation of food, often evil smelling, may be the chief symptom and such regurgitation may be spontaneous, or manually produced by firm pressure on the sac Borborygmi may be heard in the neck during swallowing and may



Fig 19 13



Fig 19 14

Fig 19 13 —Barium swallow showing a very small diverticulum in the classical site
This patient had slight dysphagia and there was spasm of the crico pharyngeus When the actual barium swallow was studied a marked hesitancy of relaxation of the crico pharyngeus was obvious

Fig 19 14 —A well developed pharyngo oesophageal diverticulum
Note that the pouch has filled before any barium has passed beyond the crico pharyngeus area where the bolus was held up for a considerable time

be followed by loud eructations These symptoms may interfere with sleep, often there is excessive mucus formation in the mouth In emaciated patients especially there may be serious respiratory symptoms, the result of the aspiration of regurgitated food and liquid which may cause "pneumonia", atelectasis, or lung abscess

Quite exceptionally a carcinoma may develop in the sac and equally rare is the development of a cervical infection proceeding to fistula formation But the chief complaint is a severe disturbance in swallowing

Treatment The safety of the one-stage operation has been amply proved. With careful technique, adequate suture in two layers and the pre- and post-operative use of antibiotics there is no longer any risk of mediastinitis and this has led to the discarding of two-stage operations and of diverticulopexy The operation should always be preceded (under the same anaesthetic) by an oesophagoscopic dilatation of the crico-pharyngeus muscle

Pre-operative treatment The patient should be given fluids alone for two days before operation and the sac emptied frequently by digital pressure on the left side of the neck associated with postural drainage in the head-down position careful attention is paid to dental and oral hygiene Parenteral streptomycin is started twenty four hours before operation

The operation Preliminary oesophagoscopy will show whether the crico pharyngeus is constricted or not if it is it should be gently dilated The mouth of the diverticulum will be inspected and its contents sucked out This is conducted under general anaesthesia with a cuffed tube employed to prevent any possible risk of intratracheal aspiration of pharyngo-oesophageal pouch contents The patient is placed in the position adopted for thyroidectomy with a small sandbag under the shoulders the neck being extended and rotated to the opposite side A collar incision as for thyroidectomy or an oblique incision along the line of the left sterno-mastoid muscle is used The anterior border of the sterno-mastoid is cleared meticulously over a wide area and the carotid packet of vessels containing the common carotid artery and the internal jugular vein fully exposed ready for lateral retraction In elderly patients it is important to remember that prolonged retraction on the common carotid artery may cause permanent cerebral damage The left lobe of the thyroid is fully exposed and the middle thyroid veins doubly ligated and divided if medial retraction of the left lobe of the thyroid is not easily achieved the superior thyroid vessels are ligated and divided When the thyroid has been displaced medially and held there in a curved retractor the diverticulum is exposed beneath a layer of cervical fascia it is quite exceptional to find the adventitia of the pouch fixed to the surrounding tissues and a loose layer of areolar tissue around the pouch is easily freed by scissor and blunt pledglet dissection The fundus of the sac should not be grasped in tissue forceps until it has been dissected completely free because of the risk of tearing its wall which consists almost entirely of mucous membrane which may be vulnerable Occasionally the diverticulum reaches down well into the mediastinum but can be delivered upwards with ease if the surrounding areolar tissue has been well cleared When the pouch has been isolated its junction with the pharynx is exposed meticulously It is essential to clear the angle between the neck of the diverticulum and the pharynx the pouch is then drawn laterally by traction applied through a small Duval s lung tissue forceps and the neck of the sac close to the pharyngeal wall is grasped in a Rankin or small Schumacher clamp another one is placed on the pouch which is removed by dividing the tissue flush with the clamp on the pharynx Interrupted fine silk sutures are then passed proximal to the clamp and left long on each side The clamp is then removed after the surrounding area of the neck has been carefully packed off with gauze swabs and the sutures are tied these sutures are closing tissue almost completely composed of mucous membrane the muscle of the pharynx is then brought over this suture line by further interrupted fine thread or silk sutures Penicillin powder is dusted over the area and the neck closed in two layers as after thyroidectomy a small rubber drain is left in place for 48 hours

The post-operative treatment Fluids in restricted amount are allowed 12 hours after operation and there is no need for an indwelling oesophageal tube Foods such as jelly and custard are allowed on the sixth day and on the tenth day the diet may be almost normal Streptomycin parenterally is given for 5 to 10 days after operation

Oesophageal diverticula

Although the oesophago pharyngeal diverticulum of Zenker may be caused by a faulty swallowing mechanism it is not truly oesophageal The true diverticula are seen in the

mid-thoracic oesophagus (Fig 19 12) and at its lower end (epiphrenal diverticulum), in both sites they are rare and neither group causes symptoms comparable with those of Zenker's pouch, though occasionally the epiphrenal diverticulum is responsible for severe dysphagia

Mid-thoracic oesophageal diverticula

" The middle segment of the oesophagus is regarded as the home of traction diverticula " (Johnstone, 1949) But the writer should have added " by others " for he has produced considerable evidence that most of these diverticula are in fact pulsion in origin It has



Fig 19 15 Fig 19 16

Fig 19 15—A common site for thoracic diverticula

There were no symptoms of dysphagia, the appearances being seen during a barium meal examination of a patient with duodenal ulcer

Fig 19 16—Pseudo diverticulum of oesophagus above a stricture due to hiatal hernia.

been assumed for years that tuberculous disease of the mediastinal glands may produce oesophageal adhesion and that the subsequent contraction of the fibrous tissue draws out tent-like oesophageal diverticula While it is undeniable that diverticula may be produced in this way the usual barium swallow picture of a diverticulum in this area shows anything but a " tent-like " diverticulum (Fig 19 12), the fundus of the pouch being almost invariably smooth and round In fact the picture is comparable with the colon diverticulum of diverticulosis and quite different from the spiky irregular pouches seen in diverticulitis, when the pericolic inflammatory adhesions have, by their contraction, destroyed the previous smooth outline

The relatively frequent appearance of diverticula arising from the oesophagus just at the tracheal bifurcation level suggests that some at least may have a congenital origin, as this is the site of tracheo-oesophageal fistula and where slips of oesophageal muscle are

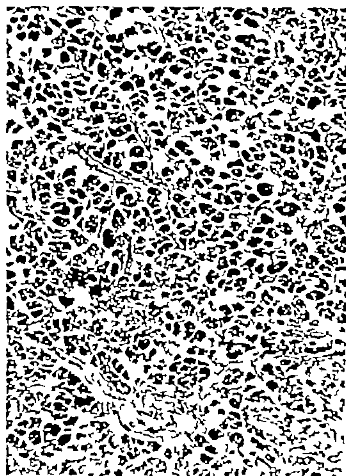
attached to the trachea or bronchus If this conception is correct the diverticula probably arise as pulsion effects in a congenitally weak area of oesophageal musculature In the rarest instance a tracheo-oesophageal fistula may develop later in life at this site the symptoms being the sudden onset of cough with evidence of lung infection the result of oesophageal contents passing into the respiratory tract Such an event is most commonly due to malignant disease of the bronchus but if bronchoscopy and oesophagoscopy exclude this the type of fistula under discussion should be borne in mind, for it is amenable to transpleural separation with closure of the defects in the trachea and oesophagus Mid thoracic diverticula are usually symptomless being discovered during routine inspections of the oesophagus when an abdominal condition such as a suspected peptic ulcer is being investigated Mild dysphagia may be a symptom when it is present oesophagoscopy should be performed to exclude lesions such as oesophagitis which may be the causative factor of the inco-ordination of the oesophageal peristalsis Operative removal of mid thoracic diverticula is only indicated if causing symptoms

Epiphrenal diverticulum

Undoubtedly a congenital type may be found for I have removed one which contained ectopic tissue such as pancreas and was associated with an aberrant artery such as commonly



(a)



(b)

Fig 10-17

(a) Operation specimen of left lower lobe and excised oesophageal diverticulum.
This child had left lower lobe bronchiectasis and an oesophageal cyst the lobe and cyst were removed together The diverticulum is clearly congenital because in its wall was found pancreatic tissue.

(b) Section of part of the wall of the oesophageal cyst shown in Fig 10-17 (a)
In addition to the pancreatic tissue shown here the cyst wall contained other elements of foregut tissue (*Brit J Surg*)

supplies an ectopic or dissociated lobe of the lung (Baar and d'Abreu, 1949) * Most of these cases, however, have the appearances of an acquired pulsion diverticulum, developing in elderly people with an area of weakened oesophageal wall (Fig 19 18) They may be associated with stenotic lesions of the lower end of the oesophagus though Johnstone has not seen the condition in over 200 patients suffering from cardiospasm Careful radiology will differentiate them from gastric diverticula seen in the condition of hiatus hernia

A not unusual type of false diverticulun is seen in patients with peptic oesophageal ulcer, the results of acid regurgitation when the hiatus is deficient, these are always seen about the area of ulceration and require differentiation from the actual ulcer crater itself (Fig 19 16) In this respect they mimic the duodenal diverticula that accompany a chronic ulcer, but are sited away from the actual ulcer

Cardiospasm

This condition and spasm of the crico-pharyngeus muscle are the most satisfactory types of dysphagia to treat and once the diagnosis has been made complete relief of symptoms usually can be achieved

Function of the lower end of the oesophagus Although there is no true cardiac sphincter, the circular muscle fibres of the lower end must relax before a bolus of food passes into the stomach Normally this happens, the hiatal musculature only prevents regurgitation of stomach contents from below and plays no part at all in holding up the passage of oesophageal contents

In cardiospasm the obstruction to the passage of food into the stomach is due to spasm of the circular muscle fibres at the lower end of the oesophagus which is itself free from intrinsic disease, and from operative experience these fibres may be much hypertrophied, since the operative details are derived from a study of long-standing examples of the disease, it is impossible to know whether this hypertrophy does in fact start at an early stage of the disease, but the disease has been seen to evolve in patients studied radiologically in whom the obstruction long preceded the dilatation of the oesophagus In the first stages of the disease the oesophagus above the area of spasm shows hypertrophy and strong powers of peristalsis, this can be readily appreciated by watching the passage of a barium swallow The first few mouthfuls of barium pass into the stomach, but then the bolus builds up above an area of constriction that marks the lower 2 to 3 cm of the oesophagus and violent secondary wave contractions develop from the region of the aortic notch down to the area of obstruction and often continue for as long as 45 minutes The cardia may then relax and allow the meal to pass on into the stomach

As the disease becomes established the oesophagus steadily dilates and becomes less actively contractile, the contractions first becoming weaker the nearer the fibres are to the spastic area Ultimately all peristaltic movements cease and the oesophagus becomes a huge distended tube which not only broadens but becomes longer, the extra length being accommodated by the development of a bend to the right—the sigma oesophagus (Figs 19 19, 19 20)

These anatomical and functional changes in the oesophagus are all secondary and not a prelude to the spasm of the muscle in the lower few centimetres of the tube and treatment directed to them and not to the cause is futile (Barrett, 1949)

Etiology The age and sex incidence might be supposed to shed light on this, the

* Davidson has also described an example of this type of diverticulum with an oesophago bronchial fistula and an associated lower accessory lobe Respiratory symptoms predominated and were cured by the surgical removal of the cyst and accessory lobe followed by suture of the oesophageal opening

condition is somewhat commoner in women than men Most of the patients first develop symptoms between the ages of 25–30 but it does arise rarely in children or even in infants It is said to arise in the highly nervous introspective types this is undoubtedly true in many instances but some patients appear to be of the most phlegmatic type A sudden onset may follow emotional disturbances such as fear and fright once the condition has developed it is not surprising that changes in character become obvious and the patients develop all types of mannerisms and are shy and apprehensive when dealing with other



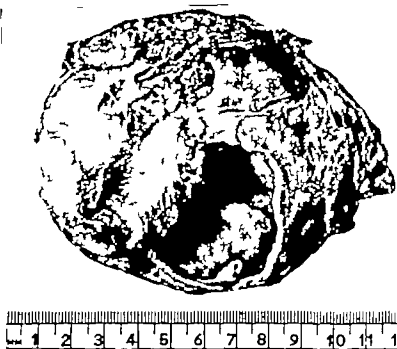


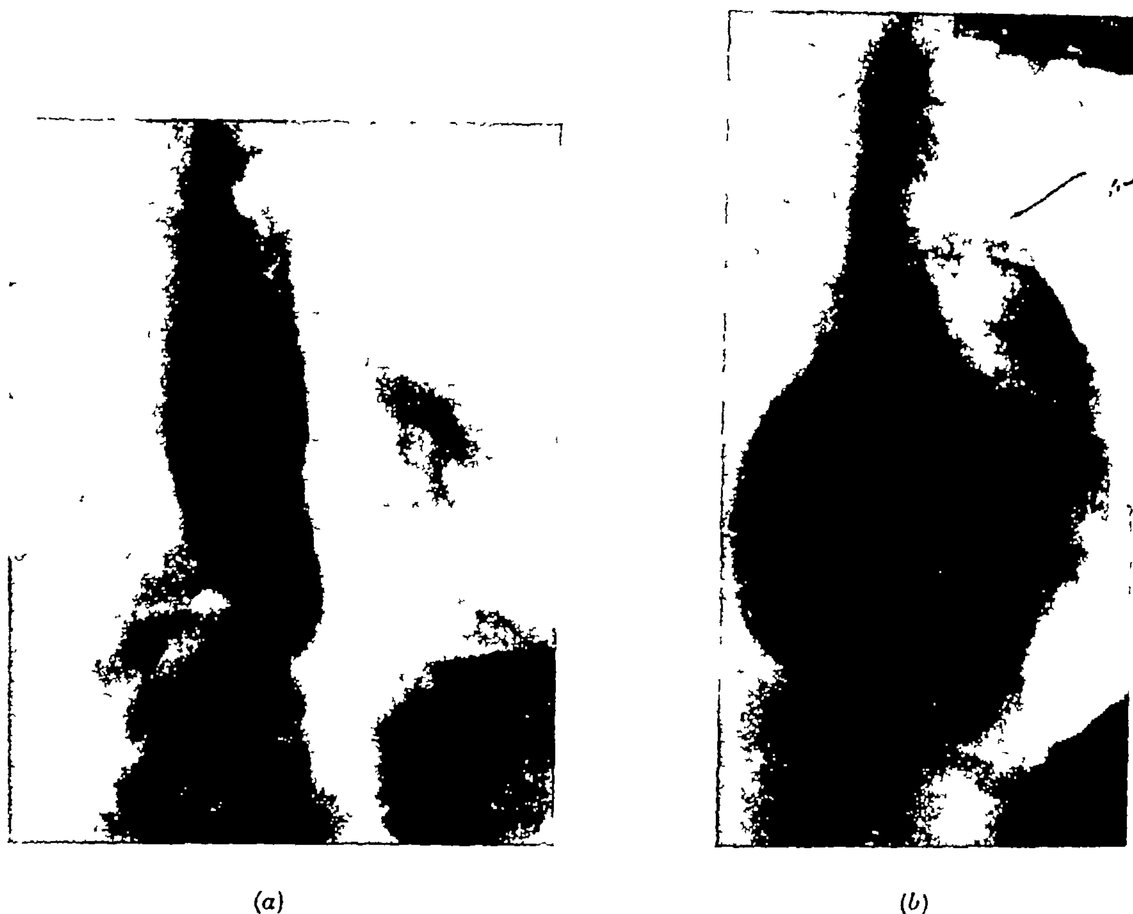
Fig 19·18 (*b*) —Epiphrenal diverticulum after excision

Fig 19·18 (*a*) —Epiphrenal diverticulum in a man of 76

Severe dysphagia after a long history of minor disturbance diverticulum excised with complete relief of symptoms.

people Whatever the original cause the fully developed state may depend on over action of the sympathetic nervous supply to the lower end of the oesophagus and this has been supported by the experimental work of Knight who produced the disease in dogs by section ing the vagi but it is a curious fact that gaseous regurgitations are a common initial phenomenon in patients who have been subjected to vagotomy for peptic ulcer of the duodenum and true cardiospasm does not follow in them although a transient obstruction is noted quite often if barium meal examinations are done early The gaseous regurgitation may be due to the pylorospasm and gastric distension that commonly follows vagotomy but even so the symptom should not arise if the cardiac muscle fibres were in constant spasm Chevalier Jackson s theory that the symptoms are the result of excessive activity of the diaphragmatic pinch-cock is not borne out by the condition seen at operation or by the excellent results that follow simple division of the circular muscle fibres at the lower end of the oesophagus without any alteration being produced in the pinch-cock mechanism

Indeed the main function of the peri-oesophageal contraction of the crural fibres of the diaphragm is to prevent regurgitation of the contents of the stomach when that organ is distended, and during the act of inspiration The disastrous results of interfering with the mechanism of the cardio-oesophageal junction and of the pinch-cock action of the diaphragm have been well described by Barrett and Franklin (1949) in their paper condemning the



(a) (b)

Fig 19 19

(a) Radiograph illustrating cardiospasm

(b) Radiograph of a patient with cardiospasm

The oesophagus below the aortic arch has distended to an astonishing degree Note that the oesophagus above the aorta has retained its tone and has not yet dilated

Both these patients were relieved of their symptoms by Heller's operation

operation of oesophago-gastrostomy for the relief of cardiospasm If the mechanism is destroyed the onset of gastric reflux may cause serious oesophagitis

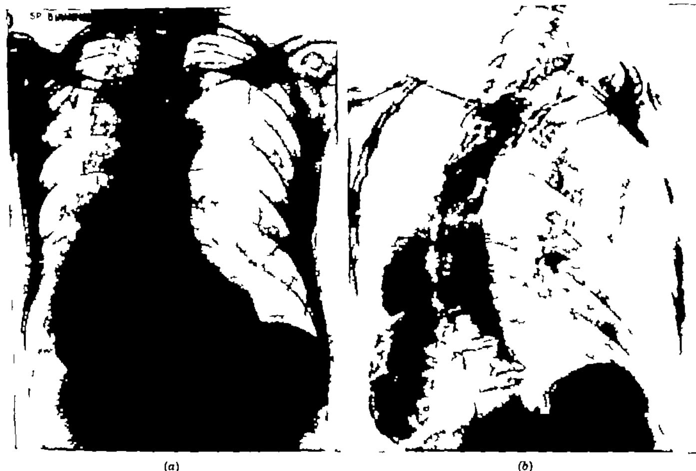
Nor can much attention be paid to the report of Rake in 1926, that there were histological changes in Auerbach's plexus, for these are probably the sequel and not the exciting cause of the disease

The term "achalasia" suggested by Hurst to indicate the failure of the sphincter muscle to open is not very helpful and fails to explain the hypertrophy of the circular muscle, often well seen during the course of Heller's operation

Symptoms The onset of dysphagia may be sudden and severe but more usually the patient has noticed a minor degree of difficulty in swallowing and the complaint is that food is sticking for a time at the lower end of the sternum, if meals are not taken very slowly and deliberately the difficulty becomes acute In this phase the patient often develops odd tricks such as swallowing against a closed glottis, momentary air-swallowing, or the

performance of peculiar thoracic movements that force the food on into the stomach Later on the symptoms become severe so that not only solids but semi-solids and fluids pass only with great difficulty regurgitation of food into the mouth becomes a constant feature, and elements of food ingested many hours previously may be seen

Regurgitation of food at night may be followed by the aspiration of decomposed oesophageal contents into the bronchi and in long-established examples of cardiospasm it



(a) (b)

Fig 10 20

(a) A straight X-ray of a grossly dilated oesophagus which extends well into the right thorax Air can be seen above the clavicle and the sigma dilatation at the lower end reaches to the right cardio-phrenic angle

(b) The distended elongated oesophagus shown in Fig 10·20 (a) is here partially outlined by a barium swallow

is quite usual to receive a history of pneumonia lung abscess or bronchiectasis The radiological study of the lungs may reveal gross changes (Fig 10 21)

Atelectasis of the lower lobes may be the result of compression of the affected bronchus by the hugely distended oesophagus but is more probably the sequel of aspiration These pulmonary complications rapidly disappear after the condition has been treated efficiently Loss of morale accompanies the loss of weight and a secondary nutritional anaemia (usually not grave) may develop Many of these patients lead a solitary life often taking their meals in companionless misery in their own bedrooms Fortunately their cure is not difficult if too much attention is not devoted to the supposed etiological feature of psycho neurosis which may persuade their doctors and relatives that if psychotherapy has failed nothing more can be attempted

Radiological investigation In advanced examples of the disease a plain radio

the chest shows an enlargement of the mediastinal shadow to the right (Figs 19 20, 19 22), and at the top of this shadow a fluid level may be seen Examination of the dilated oesophagus while barium is being swallowed shows a trickle of food through the constricted lower end of the oesophagus which is too slight to prevent the rapid accumulation of the meal above it as already said, in the early stages of the disease the oesophagus below the aortic notch shows active secondary waves of peristalsis As the dilatation progresses, these movements disappear and a great mass of barium builds up in the inert oesophagus

Typically the constricted area produces a smooth funnel-shaped appearance which



Fig 19 21

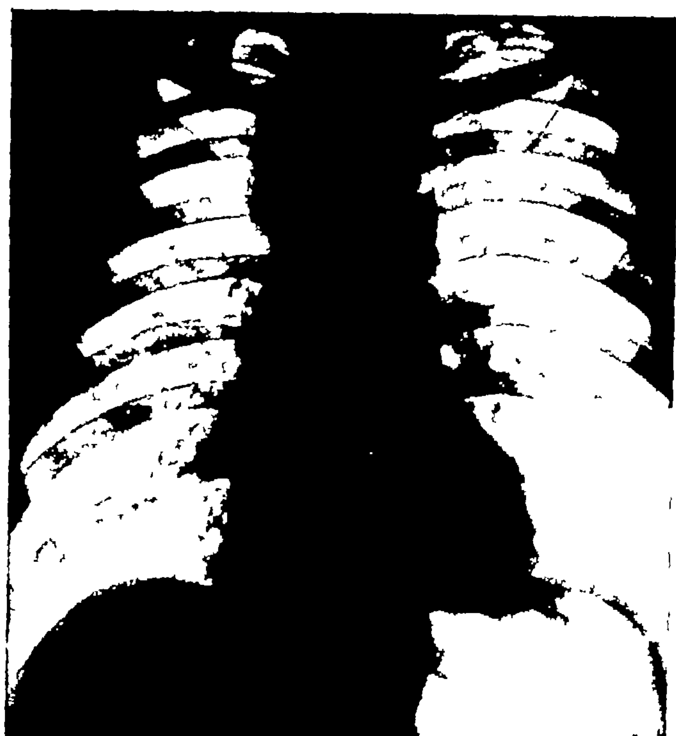


Fig 19 22

Fig 19 21 —Illustrating a respiratory complication in a patient with cardiospasm

This woman was referred to hospital with "pneumonia" There is a segmental collapse of the left upper lobe due to the aspiration of oesophageal contents

Fig 19 22 —A plain radiograph of the chest of a patient with cardiospasm

The mediastinal "tumour" seen in the right side of the chest is due to a food filled dilated oesophagus

tapers off from a dilated oesophagus which is enlarged and bent over to the right (Fig 19 19), but reliance on this radiological evidence of a benign condition at the lower end of the oesophagus in a supposed early example of cardiospasm should not be accepted, as this may lead to the failure to diagnose a carcinoma and oesophagoscopy is always to be advised (Fig 19 11) If the obsolete treatment of attempting dilatation by the daily use of mercury bougies is used on a diagnosis of cardiospasm, made solely on radiological appearances, serious mistakes may be made *

Treatment The results of modern treatment are so successful that time should not be lost in attempting psychiatric or so-called conservative therapy Several decades in which antispasmodic drugs and the attempted dilatation of the spastic area by the daily passage of Hurst's mercury bougie have provided a mass of control cases in which clinical

* A rare condition known as "lower oesophageal ring" has been described by Ingelfinger and Kramer (1953) and is said to be due to a smooth diaphragm like narrowing in this area *Open division* of this "valve" through an incision into the oesophagus has been practised by some surgeons

cure has been unusual and these methods are truly obsolete If the constricting fibres at the lower end of the oesophagus can be ruptured safely it is not unwise to say that cure will follow in nearly all the patients the important psychological measure is to assure the patient at the first consultation that cure will follow

The history of the treatment is interesting it has witnessed attempts at altering the shape of the oesophagus by plication operations and by plastic operations on the oesophago-gastric junction (cardioplasty oesophago-gastrostomy) The attack on the causative muscle hypertrophy and spasm of the muscle in the region of the cardia has been made by gentle dilatations (Hurst s mercury bougie) by forcible dilatation conducted under oesophagoscopic vision (the Russell and Negus dilator) by trans gastric digital dilatation (Mickulicz) and by actual division of the obstructing muscle fibres (Heller s oesophago-cardio gastromyotomy) The only two methods to survive are oesophagoscopic dilatation by the Russell or Negus bag and Heller's myotomy

The objections to the Hurst s mercury bougie are that it is messy and not curative the unhappy victim can at the best lead a modified social life and the frequent self passage of the instrument is scarcely ideal for introspective patients Operations designed to alter the shape of the distorted distended and elongated oesophagus fail entirely to recognize or treat the cause of these changes by pass operations of the type seen in oesophago gastrostomy or in cardioplasty produce in many patients a serious and sometimes fatal condition of inflammatory or ulcerative oesophagitis following the reflux of gastric contents into the oesophagus these pathological changes may cause severe bleeding excruciating pain and stenosing ulceration of the oesophagus If any surgeon contemplates using any operation which destroys the oesophago-gastric function of preventing reflux of gastric contents he should read the warnings given in an outstanding paper by Barrett and Franklin (1949) When the muscle at the lower end of the oesophagus and the upper part of the stomach is divided as in Heller s operation no such disagreeable effects follow for incom petence of the oesophago-gastric junction does not result evidence of this is available from the radiological examination of many patients who have been treated by myotomy and in whom radiographs taken in the Trendelenberg position after the stomach has been filled with barium show no incompetence or regurgitation

The Mickulicz operation of trans-gastric digital dilatation is condemned by a certain riskiness inherent in the method reports of rupture of the oesophagus with fatal media stinitis have been published and the margin between safety and satisfactory dilatation is a narrow one If the dilatation has been incomplete recurrence is the rule

Oesophagoscopic dilatation From all series of published results this provides the safest and least time-consuming form of therapy Vinson (1949) has performed the operation in 1 500 patients without a death and Allison has a large series in this country without fatality and with excellent results

The dilatation must not be blind oesophagoscopy is essential to exclude carcinoma or peptic ulceration as the cause of the dysphagia and to enable the operator to pass a special stilette through the narrowed cardia well into the stomach The dilator which is a bag mounted on to a hollow metal container is then threaded over the stilette until it is firmly gripped by the area of hypertrophied and over-acting muscle the bag is then gently but strongly distended by injecting water into it The cardia should be dilated up to four centimetres Essentials in the technique are to use a bag that will distend evenly so that it does not slip upwards during its filling and to dilate slowly Occasionally the dilatation has to be repeated

Heller s cardiomyotomy This operation provides very successful results It is used

for young patients, for long-standing cases in which the great elongation and distortion of the oesophagus make the safe passage of the dilator impossible, and for those patients in whom a satisfactory rupture of the muscle fibres has not been achieved It is an operation with a negligible mortality

The full division of the obstructing muscle fibres is better achieved through a thoracic than an abdominal approach A thoracotomy through the eighth left intercostal space allows a rapid approach to the lower end of the oesophagus which is mobilized in the usual way (see p 470) The oesophagus and the cardia are lifted by traction on the tapes temporarily holding the oesophagus (Fig 19 23) The fascia propria and the muscle fibres

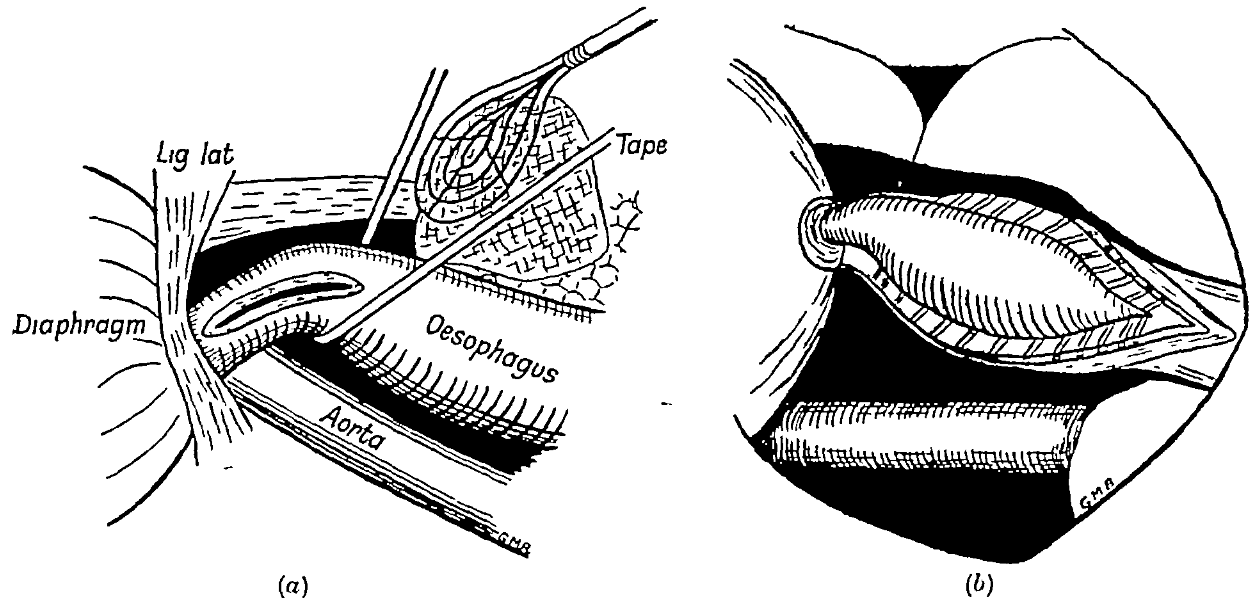


Fig 19 23 —Heller's operation

(a) The oesophagus has been lifted up by a tape and the fully inflated lung is held away by a light retractor The incision has been started in the oesophageal muscle

(b) The incision in the muscle has been completed so that the mucous membrane is prolapsing freely

are cautiously incised and then separated by a mixture of blunt and scissor dissection until the mucous membrane is clearly seen The muscle fibres are separated by scissor dissection for a distance of two inches on the oesophageal side, and one inch on the gastric side of the oesophago-gastric junction several blood vessels in the muscle layer will require ligation the mucous membrane will prolapse through the longitudinal muscle incision In very long-standing cases the mucous membrane may be friable and especial care must be taken not to open it accidentally at the actual line of oesophago-gastric union I have twice opened accidentally into the mucous membrane but on each occasion a closure with fine catgut was followed by uneventful convalescence

The divided muscle incision is left widely open and the chest is closed in the usual way Drainage is not necessary but if it is dispensed with, any pleural effusion detected on subsequent X-ray examination will be aspirated

The post-operative course in addition to the normal management of a thoracotomy is to allow fluids at once by mouth and the patient can start taking solids on the third or fourth day The usual stay in hospital is 8 to 10 days

CARCINOMA OF THE OESOPHAGUS

Since the first successful resection of the oesophagus by Torek (1913) progress has been slow until the last decade The previous obstacles to resection of the oesophagus with

restoration of continuity have been overcome by the use of effective pre and post-operative treatment by efficient safe anaesthesia and by the evolution of sound surgical techniques Although the oesophagus has no serous coat it has a thick mucous membrane which enables it to be sutured effectively to the stomach or jejunum after these have been mobilized and delivered well up into the thorax free from tension and with a carefully preserved blood supply The old fear that the oesophagus had a poor blood supply is no longer tenable or justified indeed it has excellent healing qualities and when a leakage does occur at the suture line between the divided oesophagus that has been stitched to the stomach or jejunum the fault lies in the latter and not in the oesophagus

The hazards of suppurative mediastinitis are avoided by careful surgical technique and the use of chemotherapy Oesophageal resection is being increasingly applied to a group of otherwise hopeless patients and provides great palliative benefits

Pathology and etiology The disease is far commoner in men than women being in the ratio of 9 to 1 This is the opposite from post-cricoid carcinoma at the lower end of the pharynx and upper end of the oesophagus which is rarely seen in men On the whole the disease is seen in an older age group than is usual for cancer Over three-quarters of the patients are over 50 and the average age is about 65

Common sites The British Empire Cancer Campaign figures (1942) reported 52 examples in the upper third 204 in the mid thoracic and 180 in the lower oesophagus This proportion is unfortunate in the surgical sense because the tumours in the lower third are more satisfactorily dealt with than those elsewhere Many cancers at the lower end of the oesophagus are extensions of cancer of the stomach

The type of carcinoma As would be expected the true oesophageal carcinoma is of the squamous epithelioma type (epidermoid) and the histological appearances vary from the well-differentiated type of structure to the wildly anaplastic form the latter type are naturally of a higher degree of malignancy Adeno-carcinoma may develop in the gastric lined oesophagus in the lower third of the oesophagus the finding of this type of tumour on oesophagoscopic biopsy indicates a gastric cancer

The tumours may be slowly growing and exist long before they cause severe dysphagia the extension is often around the oesophagus to produce an annular stricture and ulceration is the rule The growth may spread beneath the mucous membrane to out-crop in a different area giving the appearance of multiple seedling tumours and this may be apparent at oesophagoscopy More typically the tumour invades the muscle and later involves the loose peri-oesophageal tissues the lungs the pleura the bronchi or trachea Less frequently the pericardium heart or aorta are invaded. It is remarkable that the cancer may produce an oesophago-bronchial fistula compatible with life for several weeks though a suppurative pneumonia is usually rapidly fatal

Lymphatic spread The mediastinal lymph glands have oesophageal groups that are not regular in disposition and many nodes may be involved in the upper third of the oesophagus the lymph glands at the roots of the neck may be involved and in the lower third spread to the glands in the region of the oesophageal hiatus and along the lesser curvature of the stomach is quite frequently seen.

Symptoms and signs The growth may be well developed before real dysphagia is complained of and even with a short history the radiological and oesophagoscopic examinations may show an extensive tumour The only hope of detecting the early case is to view any derangement of swallowing with real suspicion and adopt diagnostic measures at once

Once dysphagia has developed the patient frequently but by no means invariably

indicates himself the site of the neoplasm This indication however is not to be relied upon when the patient points to the upper end of the sternum level, for not infrequently the feeling of obstruction at this point may be due to the contractions of the crico-pharyngeus muscle or of the upper end of the oesophagus (above the aortic arch) acting on a bolus of food that is actually held up a good deal lower down Solid food creates difficulty long before liquids

The advanced symptoms include severe cachexia, gross emaciation, the signs of dehydration, the complete inability to swallow even saliva and the onset of respiratory symptoms such as cough and sputum , the sudden development of a severe choking cough may indicate the rupture of the growth into the trachea or a bronchus with the production of a fistula

Continuous pain in the back usually indicates invasion of the posterior mediastinum and death may follow erosion of the aorta with a vast haematemesis as the fatal terminal event Glandular involvement of the supra-clavicular glands, or rarely of the axilla, may be detected by palpation in many patients with carcinoma of the lower and middle thirds of the oesophagus, glands in the lesser omentum are involved Metastases to the liver may occasion jaundice or ascites as well as obvious hepatic enlargement Pleural effusion is a late and not common finding · quite rarely too there may be a chylous, milky effusion into the thorax when the lymphatic duct has been invaded and blocked

Diagnosis. *Radiology* This is an essential investigation but does not provide conclusive proof of carcinoma or certain evidence that a growth is not present. In spite of the usual long history of dyspepsia followed by an insidious dysphagia, peptic ulcers of the oesophagus may be diagnosed as oesophageal cancers on radiological findings Equally perplexing may be a radiological demonstration of what appears to be a typical example of cardiospasm and yet may be in fact due to carcinoma of the upper third of the stomach (Fig 19 11) A radiological diagnosis of " carcinoma " should be confirmed by direct visualization through the oesophagoscope and a positive biopsy obtained before oesophagectomy is considered

Characteristic appearances are the loss of oesophageal contractions and a filling defect at the site of the tumour , the barium trickles through an irregular channel The gullet above the malignant stricture does not usually dilate, but if the obstruction has been present for some months, clearly will do so (Fig 19 25)

When the obstruction is at the lower end of the oesophagus the barium that escapes into the stomach may provide a filling defect characteristic of gastric carcinoma

Oesophagoscopy Any patient with dysphagia in whom a neurological lesion or a disease of the upper respiratory or pharyngeal area has been excluded should be oesophagoscoped, however clear the radiological diagnosis of a particular lesion may appear Such an examination may alter what appeared to be an unequivocal diagnosis , as already mentioned it is particularly dangerous to rely on a radiological diagnosis of cardiospasm as the appearances may mimic those presented by a carcinoma of the cardiac portion of the stomach Leigh Collis has shown me two patients with undoubted cardiospasm who had oesophageal cancers above the area of spasm , he resected both successfully The commonest radiological error is to confuse carcinoma of the oesophagus with oesophageal ulcer, especially in elderly people Oesophagoscopy is a safe simple procedure easily performed under local anaesthesia

At oesophagoscopy three important facts require assessment

(i) The appearance of the tumour and its histological nature as obtained from biopsy specimens

(ii) The exact distance of the growth from the upper incisor teeth. In this respect it is important to remember that radiological impressions may be erroneous often indicating an excessive length of oesophageal involvement due to areas of inactivity or spasm above and below the cancer site

(iii) The degree of fixity of the tumour this point may be of importance in deciding whether the tumour is operable or not If the carcinoma is in the upper or middle third of the gullet bronchoscopy should be undertaken at the same time to confirm or exclude bronchial involvement



Fig 19·24



Fig 19·25

Fig 19·24 —Carcinoma of the lower end of the oesophagus, proved by biopsy and operation

Fig 19·25 —Carcinoma of the mid-thoracic oesophagus.
The dilatation above this was considerable and such an appearance is not uncommon in patient with peptic ulceration and stricture
Biopsy = squamous epithelioma

Assessment of operability The age of the patient is an important factor Although men over 70 have successfully undergone resection and restoration of continuity it is unusual for patients in the eighth decade to survive this formidable operation though naturally each case must be judged on the basis of the general condition the state of the cardio-vascular and respiratory systems and of the renal function Many of these patients have advanced arthritis of the spine which adds to the risk of post-operative lung *atelectasis* Metastases to the supra-clavicular glands to the liver or to the lung hilum naturally indicate

inoperability severe pain in the back at the site of the cancer usually indicates a spread of the tumour beyond the peri-oesophageal tissues recent cough of severity suggests bronchial involvement, this is especially so when the cancer is sited near the left main bronchus, a rather unusual but unfortunate situation as these growths are rarely resectable

Is resection a justifiable procedure? It is clear that the ultimate survival rate of patients with this disease is poor and it is tempting to accept the position as surgically hopeless. Palliative results in which the patient can swallow normally, however, are very well worth while and even if the expectation of life is short, much misery can be avoided

My colleague, Leigh Collis, has kindly allowed me to use his material Between 1947–1956 he treated 336 cases in the Birmingham area as follows

Radical resection	150	44 per cent
Explored	62	19 per cent
Various palliative measures, e g Souttar's tube, etc	124	37 per cent

The operative mortality (deaths in hospital) was as follows

Cases 1–50	Mortality 52 per cent
Cases 50–150	Mortality 14 per cent

Most of the operations were done as palliative procedures with glandular involvement the rule The expectation of being alive two years after the operation, including the *operative mortality, was as follows*

Mid-thoracic oesophagus (1) where the growth reached the level of the middle of the arch of the aorta or above	22 per cent
Mid-thoracic oesophagus (2) growths below the level of (1) but not within the last two inches of the lower end of the oesophagus	27 per cent
Lower end of the oesophagus	21 per cent

If the gravity of the disease and its attendant misery is remembered these figures certainly belie the argument that surgical treatment is unjustifiable

Pre-operative treatment. At least a week should be devoted to this it includes attention to pre-operative breathing exercises, to the maintenance of adequate nutrition, the correction of dehydration and the elimination of oral sepsis Solid food is completely withheld and the abandonment of the futile and irritating efforts to swallow such food often leads to a considerable improvement in the swallowing of liquid foods, which should be of a high caloric value (see p 562) Vitamins should be given in full therapeutic doses, orally and parenterally An adequate intake of iron is valuable If the fluid requirements cannot be met by swallowing, intravenous administration of glucose saline or Hartmann's solution is necessary We have been disappointed in the use of intravenous amino acids as a high proportion are excreted by the kidneys Even if anaemia is slight, blood transfusion should be employed before as well as during and after the operation Penicillin and streptomycin is given parenterally for 48 hours before the operation

A preliminary gastrostomy should be avoided as far as possible, such an artificial opening not only interferes with the technique of the operation of resection and the restoration of the alimentary canal but has a disturbing effect on the morale of the patient If artificial feeding is essential a jejunostomy has advantages over gastrostomy if the stomach and not the jejunum is to be used for the oesophageal anastomosis

Operative procedures. There are fundamental differences in the surgical approach to oesophageal resection but in all, the first aim is the resection of the tumour-bearing area together with a wide margin of healthy tissue and the associated lymphatics, although this ideal is not always attainable At the lower end of the oesophagus the actual origin

of the cancerous obstruction is often in the cardia of the stomach and the logical excision then is a total gastrectomy a high division of the oesophagus about the level of the inferior pulmonary vein and a wide removal of lymphatic areas in the inferior mediastinum of the lesser and greater omentum and of all the associated gastric lymphatic glands this necessitates the removal of the spleen and the left half of the pancreas (Allison) Present-day opinion is moving away from total gastrectomy in such patients as the five-year survival rate scarcely justifies a procedure which leaves the patient with severe anaemia malnutrition and diarrhoea The less radical measure of partial oesophago gastrectomy followed by oesophago-gastrostomy is often employed

The chief differences in the surgical operations employed relate to the line of approach e g through left or right pleural cavity and to the methods used for restoring the continuity of the alimentary tract the aim is always to avoid a permanent gastrostomy As the results of oesophagectomy for mid thoracic cancer are poor in advanced examples it may be better sometimes to employ palliation by Souttar s tube (see page 475) sometimes a plastic tube may be sutured in place after partial oesophagectomy (Berman 1952)

The disadvantage of employing the stomach, which is brought high up into the thorax is the danger of subsequent oesophagitis and peptic ulcer due to the reflux of gastric juice in the absence of any diaphragmatic pinch-cock mechanism For this reason the jejunum rather than the stomach may be used. Technically however the jejunum is not available if the oesophagus has to be divided high up in the thorax and the stomach used As an alternative the isolated transverse colon can be interposed between the upper oesophagus and the stomach but this is not often indicated in cancer though ideal in the treatment of benign stricture

Right or left thoracotomy for the exposure Because of the ease of exposure of the oesophagus along the major portion of its length in the right pleural approach some surgeons prefer to plan their operation on the basis of right transpleural thoracotomy By opening the mediastinal pleura and dividing and ligating the azygos vein the oesophagus is easily dissected from its bed if the stomach is to be utilized for the anastomosis it can be mobilized by an abdominal approach and delivered into the right pleural cavity The drawbacks of the right transpleural approach are four

(*a*) The abdomen usually must be opened by a separate incision to allow the stomach to be mobilized effectively it is difficult to execute the resection and anastomosis through one major incision as it is if the left side of the chest is selected In some patients the stomach can be mobilized through the divided oesophageal hiatus from the right pleural cavity * After this preliminary abdominal operation the patient s position must be altered to enable a major thoracotomy to be performed Moreover the mobilization of the stomach is more difficult through an abdominal incision than through a left thoraco-laparotomy approach

(*b*) Operability cannot be assessed until the thorax has been explored if the condition is found to be inoperable an unnecessarily large and futile abdominal procedure has been carried out

(*c*) The stomach perhaps can be placed higher in the left pleural cavity than in the

* Belsey employs a right-sided approach for mid thoracic tumours and delivers the stomach through the oesophageal hiatus without doing laparotomy Moore (1955) has described a right-sided approach followed by a division of the sternum and left-sided paramedian incision which enables the operation to be executed without any change of position on the table Waddell and Scannell have used an anterior approach for excision of carcinoma of the superior mediastinal and cervical segments of the oesophagus (see Fig 19 26)

right and this is of great value when a highly placed oesophageal cancer has been resected

(*d*) The jejunum can be used for the anastomosis more readily on the left side than on the right and for some oesophageal cancers the operation of resection followed by oesophago-jejunostomy may be required

The main objections to the use of the left-sided approach are that the oesophagus is more deeply placed and partially covered by the aorta, this latter objection is scarcely valid in the operable case, as the oesophagus can be easily freed behind the aortic arch and if necessary brought out in front of it, so that an anastomosis can be effected in front of the great vessel (ante-aortic anastomosis, Fig 19 27) Many thoracic surgeons favour the left-sided approach because it is free from the main disadvantages outlined above The right-sided approach, however, is excellent for many mid-thoracic oesophageal cancers

Resection of carcinoma at the lower end of the oesophagus. *Anaesthesia* Pentothal, curare and oxygen delivered through an intratracheal tube may be supplemented by nitrous oxide The use of an intratracheal tube may increase the risk of post-operative pulmonary complication from a traumatic tracheitis, but the control of lung inflation or deflation obtainable by this method is more reliable than that provided by a close-fitting face-mask During these long operations the lung must be kept well inflated, the lung is deflated somewhat at particular phases of the operation when a diminution in its actual size is necessary for certain surgical procedures An intravenous saline drip is set up before the operation commences and blood is later substituted

The incision With the patient lying in the lateral thoracotomy position a long incision is made from the angle of the eighth rib along its length, across the costal margin and well *on to the abdomen to a point about one inch above and one inch to the left of the umbilicus* Before the eighth rib is resected the small abdominal portion of the incision is deepened and the left rectus muscle is completely divided obliquely and often part of the right rectus The peritoneum is then opened to examine the stomach and liver so that operability can be assessed The presence of liver metastases or gross gastric or glandular involvement does not exclude the palliative procedures. The chief symptom, the grossly distressing dysphagia, can still be relieved

If the operation, whether it be radical or palliative, is to proceed, the eighth rib is resected sub-periosteally from its angle up to and including its costal cartilage and the pleural cavity widely opened, a rib retractor (Tudor Edwards' or Price Thomas' type) being used The lung is held upwards and medially in a large moist abdominal swab so that the triangle between the lower part of the thoracic aorta and the pericardium is clearly exposed The mediastinal pleura in this area is then incised from the diaphragm to the level of the inferior pulmonary vein and the oesophagus exposed this is cleared from its bed A linen tape is passed round the oesophagus above the area of the growth, until this has been done or attempted, operability cannot be assessed The growth may have invaded glands, if these are in close contact with the oesophagus itself the growth is still resectable the same applies to involvement of glands around the inferior pulmonary veins, for these can be excised together with the loose areolar tissue of the mediastinal tunnel in which the oesophagus lies The growth may have involved the right pleural membrane, but in certain instances part of this can be excised together with the tumour, as the intratracheal anaesthesia will maintain satisfactory pulmonary ventilation even with both pleural cavities widely opened. Extensive mediastinal involvement and spread to the aortic wall make the case inoperable, areas of involved diaphragm can be excised *en bloc* with the tumour. If it is invaded the whole oesophageal hiatal ring must be removed

If the preliminary biopsy has revealed the tumour to be a squamous epithelioma and not an adeno-carcinoma the oesophagus well above the tumour and the cardiac end of the stomach will be resected together with all adjacent lymphatic tissue If the tumour is an adeno-carcinoma and arises from the cardiac end of the stomach the correct procedure usually is total or partial gastrectomy with a wide removal of lymphatics and possibly splenectomy and partial pancreatectomy (p 563)

It is wrong to think of squamous carcinoma of the lower end of the oesophagus as a lesion confined to the thorax In many patients the tumour spreads downwards to involve

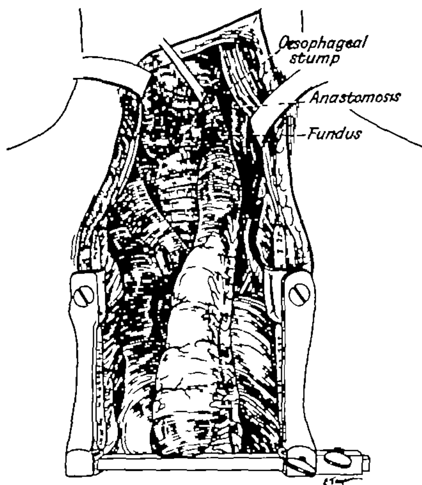


Fig 19 20 —Transternal approach to the oesophagus.
The stomach passing through the anterior mediastinum has been anastomosed to the uppermost portion of the oesophagus after oesophagectomy
(By courtesy of Dr Waddell and Dr Scannell, Boston U.S.A., and *J Thorac. Surg*)

the stomach and glands are frequently infiltrated along the lesser curvature of the stomach the radical resection required is then a removal of most of the stomach and the whole of the lesser omentum followed by oesophago-gastrostomy or oesophago-jejunostomy

Resection followed by oesophago-gastrostomy The diaphragm is divided along a line at right angles to the combined thoraco-abdominal oblique incision down to the oesophageal hiatus As the surgeon divides the muscle the assistant passes and ties separate thread or silk sutures on each side of the incision this provides careful haemostasis and the ligatures grasped separately on each side in artery forceps hold the edges of the cut diaphragm apart and so provide retraction

The abdominal and thoracic cavities are widely explored through a single large incision The next stage in the operation is to prepare the stomach for its high transposition into the

left pleural cavity The spleen is usually preserved but may be removed if the upper two-thirds of the stomach requires resection; if splenectomy is indicated the spleen is held medially and the lienorenal ligament is incised to expose the splenic vein and artery which are divided between ligatures · the lesser sac is opened and the vasa brevia secured and divided The vessels along the greater curvature of the stomach are isolated to the distal third of its length and tied and divided as close to the transverse colon as possible to preserve the gastro-epiploic arch If the spleen is to be left intact the vessels in the gastro-splenic omentum are divided and ligated

Working downward from the oesophagus the loose tissue around it, as it lies in the hiatus is cleared and the left gastric artery divided as it leaves the coeliac axis as much of the lesser omentum as is necessary is divided With the stomach so mobilized and receiving its blood supply from the pyloric vessels and the right gastro-epiploic arch, it can be lifted well up into the thorax The oesophagus well above the growth is freed from surrounding mediastinal tissue with excision of as much loose tissue and lymphatic areas as possible during this dissection if the right pleural membrane is invaded portions of it are removed.

The stomach is then divided so that a long tube can be made of the greater curvature, the lesser curve being removed with the oesophagus at a later state of the operation A clamp is placed on the part of the stomach to be resected The incision below this clamp is closed suture by suture as the stomach cavity is opened without the use of clamps The oesophagus well above the growth is divided, the upper end being held lightly in a Crafoord aortic clamp it is then anastomosed in two layers with 0000 silk to the tube of stomach which has been brought up into the mediastinum on the oesophageal side, chief reliance in the anastomosing process will be placed on those stitches that hold the stout oesophageal mucosa The anastomosis is reinforced by interrupted sutures through the fascia propria and the muscle wall of the oesophagus and the gastric serosa

The essence of safety lies in securing an anastomosis quite free from tension and to obtain this, the mobilization of the stomach must have been satisfactory It may be sometimes necessary to mobilize the peritoneum on the outer side of the duodenum

The whole anastomosis is then steadied by a few interrupted sutures anchoring it to the parietal pleura, in doing this it is important to avoid placing the stitches over the serosa covering the aorta In one of my patients an ulcer developed in the stomach at the site of such a suture and caused a fatal haemorrhage six weeks later

A pedicled pleural flap fashioned from the parietal pleura is wrapped round the anastomosis to which it is secured by a few interrupted sutures

The diaphragm is then closed, a few interrupted sutures being placed to unite it to the stomach wall Penicillin powder is insufflated over the anastomosis area and the chest and abdominal wall closed in layers according to the usual technique

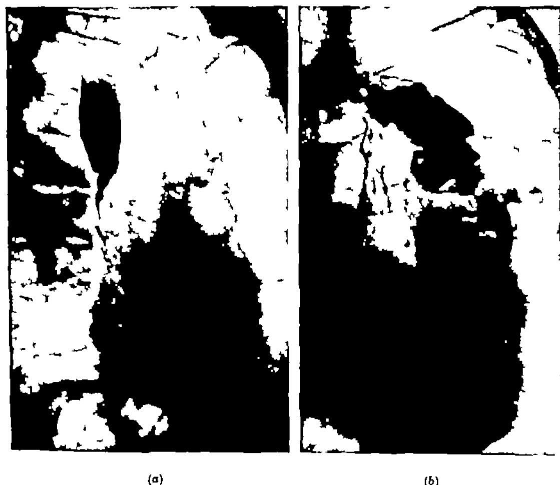
An intercostal drain is placed close to the anastomosis and the lung is fully re-expanded at the close of the operation The tube is retained for 24 hours and the lung and pleural state estimated by portable X-ray photographs The care of post-operative lung collapse and of pleural effusion is along the usual lines. At the close of the operation the oesophagus and tracheal tube should be thoroughly aspirated under direct vision through the oesophagoscope and bronchoscope

Post-operative management This follows the routine indicated on page 567 for total gastrectomy and guided by the principles discussed in Chapter 5

Resection followed by oesophago-jejunostomy. The use of the stomach for the performance of the anastomosis has the advantages of greater simplicity and greater ease

in execution physiologically it allows the swallowed food to have the undoubted advantage of gastric digestion before passing on into the small intestine Its chief disadvantage is that it leaves the patient without any physiological sphincter and undoubtedly the regurgitation of acid into the oesophagus can produce oesophagitis and peptic ulceration in some of the patients especially those in the younger age group For this reason oesophago jejunostomy has some advances its main disadvantage is that it is often followed by severe diarrhoea and malnutrition (Brain 1951) The operation of oesophago jejunostomy whether as a palliative short-circuiting procedure or as part of a radical resection is described on page 445 Oesophago jejuno-gastrostomy or oesophago-colo-gastrostomy may be better

Operation for growths of the mid-thoracic oesophagus These are less satisfactory than for carcinoma in the lower oesophagus and the results are not so good probably



(a) (b)

Fig 10-27 —Radiograph after ante-aortic anastomosis following excision of carcinoma of the mid thoracic oesophagus
(a) Before operation.
(b) After operation

because of the rapidity of glandular involvement and the difficulty of securing a really radical excision

If the growth is well below the aortic arch the procedure as described for growths of the lower end can be employed If however the tumour is so situated that a satisfactory excision is not possible below the aortic arch the divided and freed oesophagus must be cleared up to the arch itself the parietal pleura above the aortic arch is freely divided a tape or tapes placed around the aortic arch, which is then lifted upwards from the

oesophagus It is safer to dissect the aorta off the oesophagus than to attempt the reverse process (Allison) Vessels coming off the aorta itself are ligated and divided, including those supplying the oesophagus and possibly the bronchial arteries The oesophagus is then delivered above the arch of the aorta in front of which the anastomosis is made (ante-aortic anastomosis) For this procedure it is essential to have a very full mobilization of the stomach but usually it can be delivered quite readily up to the level of the clavicle

The surgical exposure for this high anastomosis may be inadequate through the eighth rib thoracotomy a further exposure may be obtained by a resection of the fifth rib in its entire length and a second thoracotomy made through its bed Alternatively the back ends of the seventh, sixth and fifth ribs may be shingled

Carcinoma of the mid-thoracic oesophagus can well be treated through a right thoracotomy incision the stomach must be mobilized by an abdominal operation or by the modifications described on page 469 After the laparotomy incision has been closed the patient is placed on the left side and a right thoracotomy performed through the bed of the resected fifth rib

The oesophagus is then mobilized and is easily accessible , in the upper part of this dissection the azygos vein is doubly ligated and divided

The stomach is then drawn up through the oesophageal hiatus and a high anastomosis is easily obtained (Fig 19 28)

Palliative treatment for inoperable carcinoma of the oesophagus. *If resection* followed by oesophago-gastrostomy or oesophago-jejunostomy is not possible because of the general or local state of the patient, gastrostomy should be avoided as long as possible Apart from the misery of this condition most of the patients do not survive their stay in hospital The most satisfactory relief is produced by Souttar's tube which is placed in the area of stenosis through the oesophagoscope by this means fluid and even solids can be swallowed and this relieves the worst feature of oesophageal obstruction, namely thirst The palliation it provides may enable the patient to obtain reasonable comfort for two to six months *

Radiotherapy is of undoubted value in some patients The disappearance of the tumour mass may be followed by a cicatricial fibrosis and at all stages no hesitation should be felt about repeating the oesophagoscopy and dilating such strictures or canalizing them by a Souttar's tube (see Fig 19 29) Smithers (1957) has given an encouraging account of radiotherapeutic control of oesophageal cancer, especially of the upper third

BENIGN TUMOURS OF THE OESOPHAGUS

These rare tumours fall mainly into two groups, fibro-lipoma and *leiomyoma* . the fibro-lipoma is a quite fantastic tumour which arises from the mucous membrane of the cervical oesophagus to which it is attached by a well-defined stalk The pedunculated mass may grow to large proportions which may cause dysphagia but classically is projected through the mouth during an attack of violent vomiting to the great discomfiture of the patient ! They are removed by open operation, which usually consists of a cervical approach but may also require thoracotomy (Clagett) The leiomyoma is an encapsulated tumour, seen in the thoracic oesophagus, and growing between the mucous membrane and the

* I have two patients who lived in reasonable comfort 18 months after the palliative use of Souttar's tube , both were patients with squamous epithelioma of the oesophagus proved by histological examination of biopsy material



FIG 10-28 —Radiograph of the chest a year after excision of the oesophagus for carcinoma
The stomach has been anastomosed to the cervical oesophagus through a right thoracic approach.

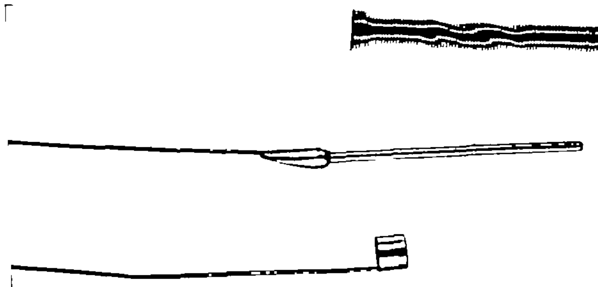


FIG 10-29 —Souttar's tube with the two introducing instruments.
These are readily inserted under direct vision through an oesophagoscope

adventitia, causing discomfort rather than dysphagia until they are truly enormous. ' may present as mediastinal tumours, a sarcomatous type is rare The barium swa radiograph is characteristic (Fig 19 30) because of the slow growing rate of these tum the gullet also may be dilated Oesophagoscopy reveals the bulging in of an intact mu membrane

The tumours are resected through a thoracotomy incision the involved area of oesophagus is fully exposed before it is mobilized and lifted out by an encircling piec linen tape An incision is then made through the muscle overlying the tumour, which be shelled out, often without any opening being made into the lumen of the gullet oesophageal wall is closed in two layers with fine interrupted silk or thread sutures the chest temporarily drained by a water-sealed intercostal tube

In the unusual type which has a pedunculated base with prolapse of the tumour the lumen, the oesophagus is deliberately opened and the tumour removed the mu membrane is then carefully closed by interrupted sutures Clagett (Johnston, 1953) his colleagues at the Mayo Clinic have published a full account of these tumours

TRACHEO-OESOPHAGEAL AND BRONCHO-OESOPHAGEAL FISTULAE
(Non-congenital)

Malignant disease

The commonest cause of acquired tracheo- or broncho-oesophageal fistulae is malign disease usually of the lung, sometimes of the oesophagus and rarely of the trachea combination of oesophageal symptoms with those of the lung should soon lead to detec of the cause by clinical, radiological and endoscopic examinations Quite exceptionally diagnosis may be dramatic when during the course of a barium swallow examinatio the oesophagus the opaque meal is seen to flood the bronchial tree under the viewing scr

The treatment of such malignant fistulae can only be symptomatic gastrostom rarely justifiable though in one patient who had been known to have an inoperable bronc carcinoma for a year three months' satisfactory relief from constant choking was provi by this method Dysphagia in malignant disease of the lung is more often due to glandu involvement than to spread of the tumour to the oesophagus

A malignant tracheo-oesophageal fistula may occasionally be amenable to Wooke operation in which the larynx and lower part of the pharynx are resected a perman tracheotomy is of course, essential but the pharyngeal defect can be closed by pla operations

Acquired non-malignant fistula (oesophago-bronchial)

(*a*) *Acute inflammatory conditions as the cause* Extremely rarely a pyogenic pleu empyema may rupture into the oesophagus actinomycosis may produce such a co munication The previous pleuro-pulmonary symptoms will be complicated by choki especially during the swallowing of food or liquids, or occasionally the vomiting of p The investigation of such symptoms should be by a lipiodol swallow examination and oesophagoscopy the treatment essentially is adequate drainage of the empyema patients suffering from actinomycosis, penicillin therapy combined with sulphonamid and iodine should be followed by a prolonged course of carefully graduated doses of de X-rays

(*b*) *Chronic inflammation* In a few patients after thoracoplasty or pneumonectomy for tuberculosis a serious fistula may develop months or years later the essential operative detail in the treatment of these is to free the oesophagus from its surrounding cuirass of fibrous tissue above and below the fistula before it is closed in two layers Krause of Freiburg has described this fully Sometimes bronchiectasis of a lobe may be associated with the fistula I have seen this in a case of middle lobe bronchiectasis associated with one of these fistulae After the middle lobe had been removed the opening into the oesophagus was easily closed in two layers after its edges had been excised



(*a*) (*b*)

Fig 19·30 —Leiomyoma of the oesophagus. Man of 24

(*a*) Barium swallow This shows delay at tumour site the mucosal pattern is disrupted and the mass bulges into the lumen and rises from the oesophageal wall anteriorly Leiomyoma is the most likely diagnosis (Dr Oliver Smith)
(*b*) Photograph of excised leiomyoma—note potato-like mass these tumours are often multiple

Occasionally a fistula is discovered in an adult at the site where congenital tracheo oesophageal communications occur At operation for the closure of these abnormal connections after the oesophagus has been well cleared above and below the area of the fistula, its actual track which is usually short and of narrow calibre may appear to be singularly free from evidence of inflammation The tracheal and oesophageal openings are closed by interrupted thread or silk sutures and attached pleural flaps sutured over the raw edges Congenital or acquired oesophageal diverticula may communicate with a bronchus (page 456)

Perforations and tears of the oesophagus

These may be due to trauma (penetrating wounds or as the result of an accident during oesophagoscopy) to spontaneous perforation of the lower third of the tube to rupture of a peptic oesophageal ulcer to post-operative leakage after oesophago-gastrostomy or

oesophago-jejunostomy, to neoplastic processes of the oesophagus itself or of the bronchus, as a sequel to pleural empyema or as the result of tracheo-oesophageal fistulae (other than the congenital type seen in new-born infants) Though unusual they present important and difficult diagnostic problems , apart from the group due to malignant disease they are amenable to surgical treatment

(*a*) *Traumatic laceration* The accidental perforation of the posterior pharyngeal wall or of the thoracic oesophagus during oesophagoscopy is more readily recognizable than the other varieties because the accident is probably obvious at the moment of its infliction or because the serious symptoms and signs of perforation will be apparent in a few hours' time while the patient is still under hospital care Pain, pyrexia, subcutaneous emphysema and pneumothorax after oesophagoscopy will indicate the need for immediate exploration of the neck or thorax (see p 58) Immediate suture in two layers, the management of any complicating pneumothorax and the use of antibiotics should be followed by survival if the catastrophe is recognized early

In gunshot or stab wounds exploration of the thorax is indicated unfortunately the oesophageal wound is usually overlooked in the early stages when attention is being directed to the correction of the physiological derangements that often follow thoracic trauma Perhaps the most important signposts are provided by the development of surgical emphysema above the clavicle, difficulty in swallowing, pleural pain and the rapid accumulation of fluid in the chest which on aspiration clearly consists of the liquids that have been swallowed In warfare most of the noted cases have been detected during the course of a formal thoracotomy for severe intrathoracic injuries or later when an empyema has developed which after drainage discloses oesophageal contents

Remarkable findings may be recorded · in one patient a stab wound of the left supraclavicular fossa was followed by the rapid accumulation of fluid in the left chest the aspiration of this withdrew large quantities of milk which the patient had swallowed after the attack In another patient a small revolver fired at point-blank range into the right supraclavicular passed across the mid-line and the bullet was easily palpable in the left axilla immediate difficulty in swallowing and breathing followed At oesophagoscopy and bronchoscopy the posterior wall of the trachea just above the bifurcation showed bruising and oedema but the oesophagus appeared quite intact fluids were withheld for three days and apart from a small right-sided haemothorax which required aspiration the patient made a complete recovery A traumatic perforation of the oesophagus into an empyema cavity due to a foreign body lodged in the body of the seventh thoracic vertebra was seen in another patient five days after wounding

In traumatic lacerations the oesophagus should be approached from the right side for wounds of the mid-thoracic region, from the left if in the lower three inches the laceration is sutured in two layers with interrupted sutures and the pleural cavity drained by water-sealed drainage

(*b*) *Spontaneous perforation of the oesophagus* There seems no doubt that the normal oesophagus can tear in its lower third after the swallowing of large amounts of food or of great quantities of fluid The tears are longitudinal and may have the appearance of a clear incised wound the absence of disease in the oesophagus may lead to the condition being overlooked even at post-mortem examination Barrett (1946) has provided a classical description of the pathological and clinical features of this rare condition , he points out that surgical cure by immediate suture of the laceration is only possible if the profession is aware of the fact that the accident does happen, that it has a definite symptomatology and can be diagnosed

Pathology and etiology Usually the tear is from 1 to 8 cm. in length in the left poste lateral aspect of the lower end of the oesophagus above the diaphragm, there being or two recorded instances in which the site was different (in one the tear ran on into t stomach and in the other it was at the level of the tracheal bifurcation) The ruptu may be small and overlooked at autopsy unless the oesophagus is tied off below the a involved and then filled with fluid from above If the tear is higher than usual the rig pleural cavity will take the oesophageal contents and in the rare instances of transve tearing both pleural cavities may be swamped

The lower end of the oesophagus is the weakest part of the tube and when it tea spontaneously the rupture will usually be in that area which is covered only by the parie pleura of the left side without the cushioning support of the aorta and the retro pericard fat

The swallowing of large meals the intake of vast quantities of fluid especially alcoholic and violent retching and vomiting are etiological factors of great importance most of the recorded cases Barrett believes that alcohol by preventing the necessa co-ordinated movements in the act of swallowing and the vomiting plays an importa etiological part Further evidence of the danger of impeded vomiting is presented Barrett when he analyses the ruptures that have developed below areas of oesophag strictures in patients who have been retching violently In most of the report histories he found accounts of violent vomiting often associated with gluttony a alcoholism

Signs and symptoms The onset is sudden dramatic and catastrophic Althou vomiting may have preceded the development of sudden agonizing pain in the upp abdomen behind the lower end of the sternum and in the base of the chest with possi referred phrenic nerve pain to the shoulders it ceases to dominate the clinical picture soon as the disaster has occurred The pain is even more intense than that associat with rupture of a peptic ulcer of the stomach and duodenum, with which the diagno is most often confused It remains quite unrelieved by morphia Cyanosis and grunti respirations are noted at the outset and the pulse rate accelerates far earlier than in t typical perforated gastric or duodenal ulcer the upper abdomen shows board like rigidi and is extremely tender an added reason for the diagnosis of perforated peptic ulcer bei made

Unfortunately the chest signs in the absence of a radiograph are in the early stag not obvious in most patients though occasionally of such magnitude that they domina the clinical picture decreased movements and the discovery of râles in the bases are n unknown in perforated gastric ulcer or acute pancreatitis If however in the diagno of normal upper abdominal catastrophes a radiographic examination were made with t patient in the upright position a fluid level due to a hydro-pneumothorax would at on establish the diagnosis which could be confirmed by the withdrawal of gastric content possibly blood-stained by thoracentesis

In a few patients surgical emphysema in the neck may indicate the rupture the oesophagus into the posterior mediastinum but such a sign is unlikely to be early one

The logical surgical treatment is by thoracotomy suture of the tear a careful cleani of the pleural cavity and closed drainage of the chest

The condition is rare but should be borne in mind in patients with the signs a symptoms of an upper abdominal catastrophe especially when this takes place after lar meals or bouts of drinking

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CHAPTER 20

MEDIASTINAL TUMOURS AND CYSTS

It is as awkward to classify these tumours as to outline the symptoms they may produce some of the " tumours " seen may be cysts and not neoplasms, remaining symptomless unless complications, such as thoracic compression, become evident Malignant tumours, usually extensions from bronchiogenic cancer, may cause the gravest symptoms, usually of superior mediastinal compression associated with gross dyspnoea and swelling of the face and hands Although the commonest tumour of the mediastinum is invasion by bronchial carcinoma and the next commonest that of lymphadenoma (Hodgkin's disease), the diagnosis of these two conditions, which are often treated by radiotherapy, must not be made lightly, for their symptoms and radiological appearances can imitate those of curable conditions such as intrathoracic goitre or mediastinal cysts (dermoid, bronchogenic or enterogenous)

A convenient classification of mediastinal tumours includes cysts which are not properly neoplastic and this listing will be followed here. A division of these tumours into simple and malignant is not as logical as might be supposed, for apart from certain types of cysts, some of the innocent tumours are potentially malignant As an example may be mentioned the malignant degeneration of the neurofibroma, a tumour sometimes alleged to be of no danger unless causing compression symptoms, Brian Blades (1941), surveying the world literature on the subject, estimated that 41 per cent of these tumours underwent sarcomatous change For this reason a classification based on the regional distribution of mediastinal tumours and cysts is more useful and the one given below is based largely on a paper by Brian Blades (1941), and from the studies of Heuer and Andrus (1946) on 230 examples

ANTERIOR MEDIASTINAL TUMOURS

1 *Carcinoma* (usually secondary to bronchial carcinoma) Rarely may arise in epithelial tissue in the thymus gland
2 *Tumours of lymphatic origin*
   (a) Hodgkin's disease Lymphoma
   (b) Lymphosarcoma
   (c) Thymoma and thymic enlargements
3 *Thoracic goitres*
4 *Dermoids and teratomata* *
5 *Pericardial cysts or pleural cysts* (" The spring-water cysts ")

POSTERIOR MEDIASTINAL TUMOURS.

1 *Carcinoma* (secondary to bronchial carcinoma)
2 *Neurogenic tumours* (usually posteriorly sited, though rarely placed elsewhere in the line of an intercostal nerve and exceptionally in the anterior mediastinum)
3 *Bronchiogenic, enterogenous or gastrogenous cysts*, most of these represent duplications of the foregut

TUMOURS ARISING ANYWHERE IN THE MEDIASTINUM

1 Lipoma
2 Fibroma—fibro-sarcoma
3 Xanthoma
4 Chondroma
5 Hydatid cysts (almost invariably secondary to hydatid disease of the lung)
6 Lymphangioma

* In two of my patients, one a dermoid cyst and the other a malignant solid teratoma, the tumours were placed in the posterior mediastinum

General aspects

The symptoms of mediastinal tumour (when symptoms are present) depend on the size rate of growth character and position of the mass The size of the tumour may bear no relation to the symptoms a small one pressing on the bronchus with resultant atelectasis of a lobe or a lung may cause severe distress while a large posteriorly sited neurofibroma may be silent Pressure effects may produce dyspnoea with stridor and this arises most commonly from a retro-sternal goitre but other tumours in the superior mediastinum may be responsible Dysphagia usually develops much later than dyspnoea being not uncommon when the mediastinum is invaded by bronchiogenic carcinoma Pain may be caused by local pressure or by a secondary pleuritic reaction due to infection in a collapsed area of lung the result of bronchial occlusion

Engorgement of the venous trunks draining the head and arms is a feature indicating a late diagnosis and an advanced degree of intrathoracic pressure the face and arms may show a dusky cyanosis and an oedema that is worse on waking in the morning The usual cause of such obstruction is a secondary malignant spread from bronchial cancer but this *should not be assumed without full investigation for the engorgement may accompany a* removable innocent tumour or an intrathoracic goitre rarely it is due to thrombosis of the superior vena cava (Tubbs 1946)

Thrombosis of the superior vena cava

Because of the diagnostic problem a brief note on this rare condition is included here The vein may become clotted in the condition associated with phlebo-thrombosis developing elsewhere, and malignant disease may be an important factor About one quarter of the patients have a curious fibrotic infiltration of the superior mediastinum the etiology of this was ascribed by Ochsner and Dixon (1936) as being due to syphilis in 11 and tuberculosis in 10 in a series of 28 examples of this condition The etiology remained obscure in 7

In one of three patients with this condition under my care the histological appearance resembled that seen in examples of Riedel s ligneous thyroiditis

Clinically these patients present the classical features of superior vena cava obstruction of slow onset swelling of the upper limbs is unusual. A full examination fails to reveal any obstructive cause such as carcinoma of the lung aneurysm or mediastinal tumour There is no effective treatment and surgery is contra indicated. A collateral circulation develops and patients have survived for many years.

Mediastinal tumours by pressure on nerves may cause intercostal pain and this is one of several reasons for avoiding the misleading diagnosis of pleurodynia or intercostal neuralgia diaphragmatic irritation with phrenic nerve pain referred to the shoulder tip or diaphragmatic paralysis may follow pressure from a mediastinal tumour innocent or malignant

The sympathetic nervous chain may be irritated by pressure or paralysed by infiltration sweating of one side of the face pupil changes and enophthalmos may be seen There may be symptoms attributable to pressure upon the vagus nerve and I have removed mediastinal tumours from three patients with symptoms suggestive of duodenal ulcer in one instance the tumour was a large posteriorly placed bronchiogenic cyst and in the other two a posterior neurofibroma was excised the alimentary symptoms were relieved in two but the third had a duodenal ulcer later successfully treated by partial gastrectomy Pressure on the recurrent laryngeal nerve may involve voice changes

Quite exceptionally the tumour may be gross enough to produce actual bulging of the chest wall (Fig 20-17) associated usually with extreme displacement of the apex beat of the heart Severe displacement of the heart may cause serious symptoms

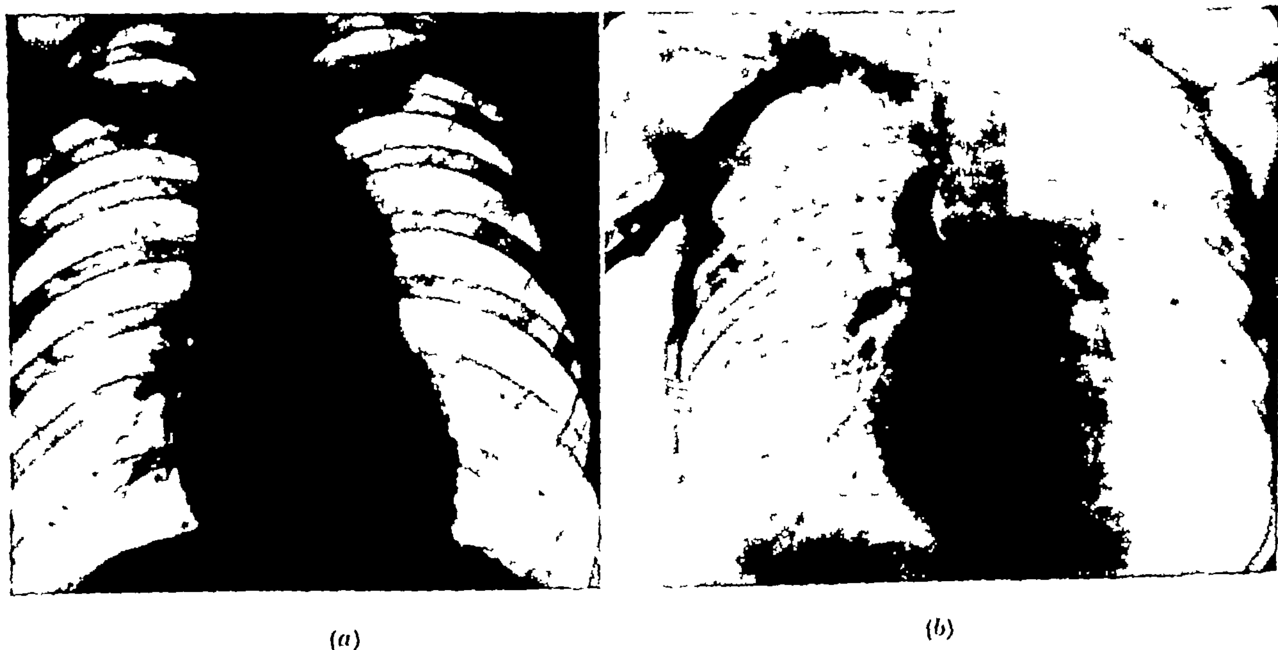
Tumours of the thymus may be associated with myasthenia gravis pure red cell anaemia (Chalmers 1954) and possibly Hodkin s disease (Thomson 1955)

Physical signs. These will depend entirely on the size and effects of the tumour. The tumour mass may produce an increase in dullness on percussion, engorgement of veins and the nerve palsies referred to above may be noted. If atelectasis of a lobe or lung is present, the appropriate signs will be detected, but the main features detectable are radiological ones.

Radiological appearance of mediastinal tumours. This is the essential diagnostic weapon and many conditions can be labelled accurately from the radiological characteristics. Screening is essential as the whole thoracic anatomy and movement require study: the radiological appearances may be confined to the delineation of the tumour alone or include secondary appearances such as atelectasis. Perhaps the most difficult examples presented for diagnosis are when much of the mediastinal shadow is enlarged as the differentiation of secondary carcinoma, of Hodgkin's disease, of malignant tumour, or simple enlargement of the thymus, aneurysm and retro-sternal goitre may be difficult on radiological appearances only. Occasionally a faulty diagnosis of pericardial effusion, cardiac enlargement or cardiac aneurysm is made. It is important to realize that many innocent mediastinal tumours show transmitted pulsation on X-ray screening whereas a considerable number of thick-walled aortic aneurysms full of laminated blood clot show no expansile pulsation at all and it is unwise to diagnose a thoracic aneurysm entirely on the results of screening.

Shadows that overlie the heart and aorta are indeed most difficult to assess and require the careful "all round the heart" screening and the added aid of a barium swallow (Fig 20 33). Angiocardiography may establish the extravascular site of the mass as in the case illustrated in Fig 20 1.

Although apparently encapsulated, circular or ovoid shadows in the lung fields are often malignant but this is not so in the case of mediastinal tumours and the clear-cut edges



(a) (b)

FIG 20 1

(a) Radiograph of a man of 28 complaining of pain in the left upper chest: a systolic murmur was heard over the pulmonary artery.

(b) Angiocardiography (Dr D Harris) shows a normal left pulmonary artery indicating the extra vascular nature of the swelling. At thoracotomy (Mr S C F Stephenson) a cyst arising from the thymus was removed. The systolic murmur disappeared. The radiological appearance of this type of cyst closely resembles the rare condition of aneurysm of the pulmonary artery.

and outlines of neurofibroma dermoid and other cysts and retro-sternal goitre are fairly reliable indications of their innocent nature

These edges tend to be blurred and indistinct when malignant change has taken place (e.g malignant neuroblastoma in children)

The location of the tumours is important retro-sternal goitres and mediastinal dermoid cysts are usually sited anteriorly and the shadow cast by an intrathoracic goitre is often typical. It is important however to remember that this is not always so and the goitre may be in a posterior mediastinal position behind the oesophagus (Tomkinson 1951)

Again the neurofibroma is usually recognized by its ovoid shape consistent density and its location in the posterior mediastinum It is not always possible to differentiate this from such conditions as bronchial or enterogenous cysts placed in the posterior mediastinum

The use of diagnostic artificial pneumothorax The need to differentiate an intra or extrapulmonary site of a tumour by taking radiographs after a diagnostic artificial pneumothorax has been blunted by the generally accepted principle that ovoid or circular intrathoracic tumours call for thoracotomy but the method may provide occasional information of value Barrett (1949) makes the interesting observation that in patients with thin walled fluid-containing cysts of the superior and pre-pericardial areas (spring water cysts see p 503) the peculiar laxity of these cysts is such that an artificial pneumothorax alters their shape and density and so is of diagnostic value

ANTERIOR MEDIASTINAL TUMOURS

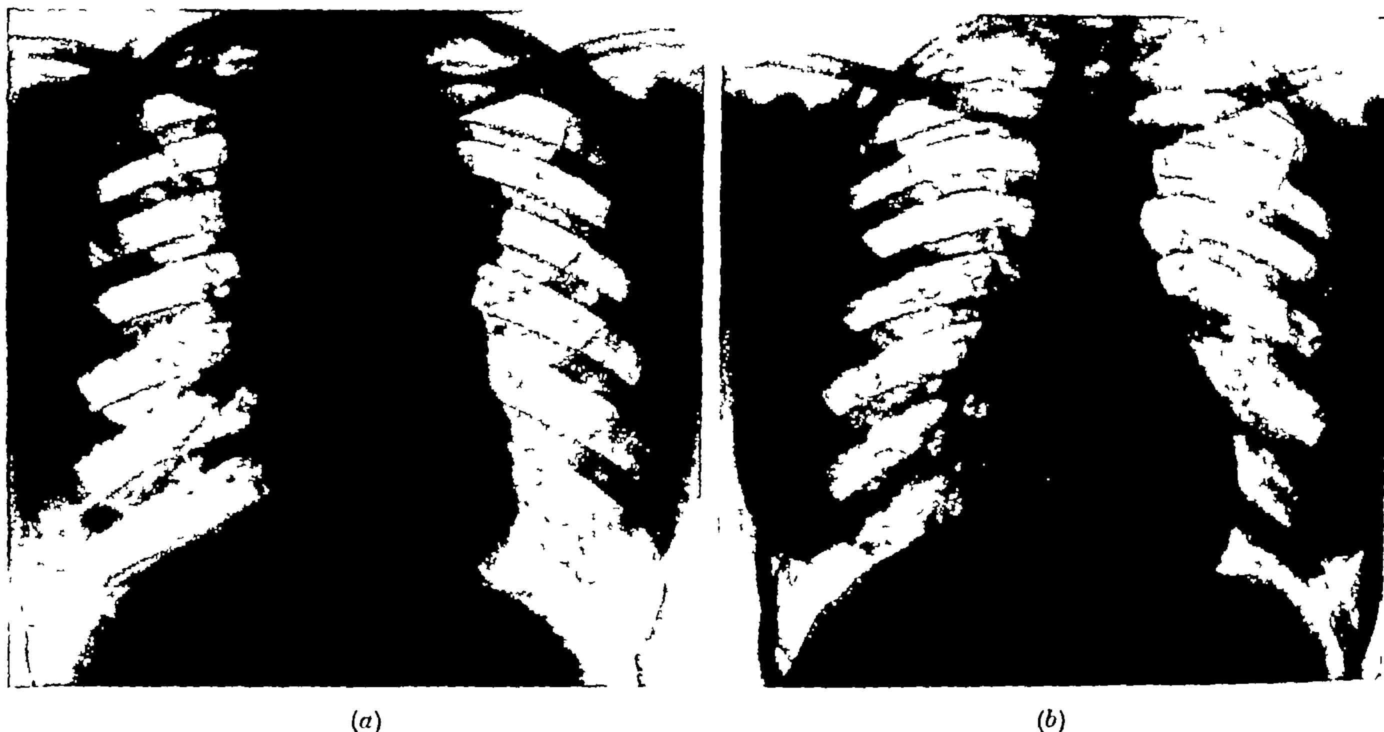
Carcinoma

Apart from the rare development of cancer in thymic tissue this condition is secondary to a bronchial carcinoma The mediastinal involvement may be gross even when the primary lung tumour is small or insignificant The condition was frequently diagnosed in earlier days as mediastinal lymphosarcoma The oat-celled carcinoma is the usual neoplasm and the spread may be rapid Less commonly the original tumour is in the oesophagus or rarely the trachea

Clinical features Cough may not be a notable symptom but its presence with the association of haemoptysis is an important clue to the correct diagnosis and the other symptoms of bronchial carcinoma may be present The mediastinal involvement may produce swelling and vascular engorgement of the face and arms often with dilatation of the veins of the neck and upper extremities frequently worse when the patient awakes in the morning Hoarseness due to the involvement of the recurrent laryngeal nerve is common dyspnoea and later dysphagia indicate the degree of superior mediastinal pressure present but the difficulty in breathing may be associated with a blood stained pleural effusion or atelectasis of a lung or a lobe of a lung the result of actual blockage of the bronchus by tumour or by the encirclement of the bronchus by enlarged glands Each of these symptoms may produce characteristic physical signs The supraclavicular glands may be enlarged The diagnosis will depend largely on radiological examination If an area of lung atelectasis is associated with a great invasion of the superior mediastinum the diagnosis of bronchial carcinoma can often be confirmed by bronchoscopy quite exceptionally these conditions may be seen with retro-sternal goitre though atelectasis is rare in that disease however severely distorted the trachea may be

Differential diagnosis Many of these cases were regarded in the past as lymphosarcoma but this condition is rare and the diagnosis is rarely acceptable on clinical or radiological

grounds in the absence of histological proof The involvement of the superior mediastinum in lymphadenoma is, however, common and in all examples of clinical thoracic compression of the superior mediastinum it is to be considered, chief difficulties will be encountered when the first lymphadenopathy to develop is in this region, typically, however, the presence of enlarged lymphatic glands in the posterior triangles of the neck, abdomen, axillae, and groin co-exist and the liver and spleen may be enlarged The diagnosis will be confirmed by biopsy of a gland from the neck or axilla If deep X-ray therapy is used there is usually a rapid temporary decrease in the mediastinal shadow, estimated radiologically



(*a*) (*b*)

FIG 20 2

(*a*) Hodgkin's disease (lymphadenoma) or ? thymic tumour (see text below)
Gross involvement of mediastinal glands
(*b*) Sixteen months later after deep X ray therapy
(Dr J Bromley s patient)

The differentiation of the condition from retro-sternal goitre is of the greatest importance, as that condition is curable by surgery and many patients are still referred to radiotherapy units for treatment while some of the patients die without reference to a surgeon (see retro-sternal goitre, p 495)

The diagnosis of bronchiogenic or gastrogenous cysts depends largely on radiological appearances The neurofibroma perhaps has the most characteristic appearance, usually presenting a clear-cut ovoid opacity with smooth edges in the posterior mediastinum

Boeck's sarcoidosis, by its involvement of the parahilar glands, may produce considerable enlargement of the mediastinum, but usually there are typical associated lesions in the lungs, with glands involved elsewhere and with changes in the eyes or spleen, or characteristic bony foci in the radiograph of the bones of the hands and feet

Hodgkin s disease lymphoma or thymic tumour ?

A D Thomson (1955) has recently enlarged on Symmers' (1933) observation that Hodgkin s disease has been known to arise from the tissue of the thymus gland and that this condition may, in fact, be thymic in origin and not a reticulosis Undoubtedly, patients

with lymphadenomatous enlargement of the lower cervical and superior mediastinal glands have been seen at operation and in the autopsy room with similar masses in the thymus Thymectomy and block dissection of the glands has been performed with apparent success before the disease has been seen in other groups of glands If in fact the disease starts as a thymic neoplasm spread to local glands is easily explained the more widespread lymphatic involvement could be ascribed to a direct spread into the thoracic duct If Thomson s theory is correct surgeons and radiotherapists must consider his questions which are as follows (1) May not the masses seen on the chest radiograph be due to thymic tumours and not necessarily enlarged lymphatic glands ? (2) Is sufficient radio therapy given to the mediastinum ? (3) Has thymectomy a place in Hodgkin s disease alone or with radiotherapy ?

Tumours and enlargements of the thymus glands

Surgical interest in the thymus gland is largely due to the work of Blalock (1939 and 1941) and Geoffrey Keynes (1946) Our inadequate knowledge of thymic physiology does not allow an accurate understanding of thymic deficiency or hyperfunction and this is accompanied by confusion concerning the pathology of thymic tumours The malignant thymoma may be called a lymphosarcoma by one pathologist and a carcinoma by another it may or may not be associated with myasthenia gravis

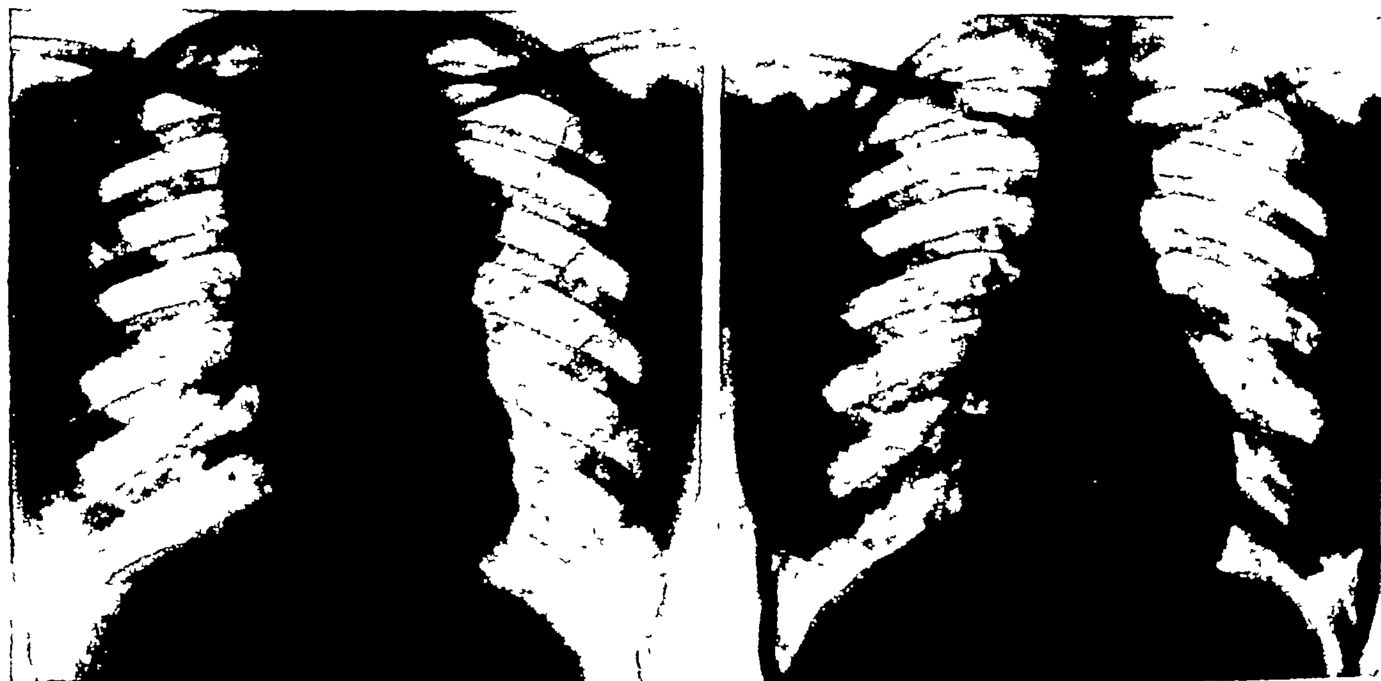


Fig *0-3 — A triangular shadow to right border of the heart in an infant A typical thymic shadow

Aberrant thymic tissue The thyro-thymic lymphatic connections are well known (Williamson and Pearse 1930) and enlarged thymic tissue is sometimes found in close contact with the lower poles of the thyroid gland thymic tissue may be found as a con glomerate mass well away from the mediastinum An example of this in a girl of 23 with no symptoms is given on page 281 a solid tumour dissected from the region of the hilum in the depths of the great fissure proved on histological examination to consist of normal thymic tissue the patient was in perfect health four years later

Thompson (1951 personal communication) has told me that in two spring water

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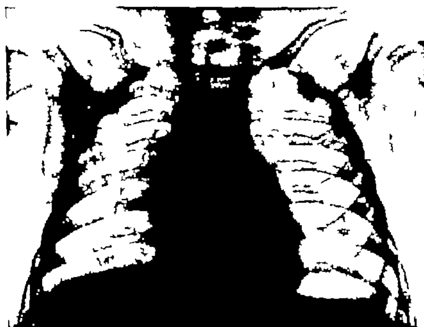


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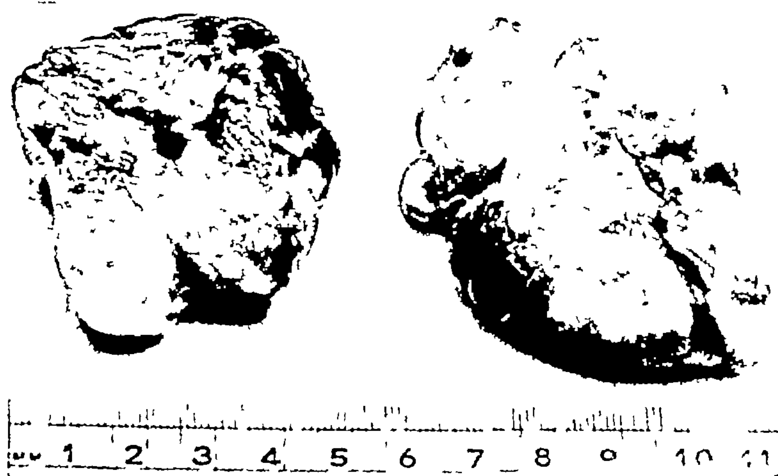
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cysts (see p 503) which he removed, thymic tissue was present in the cyst walls and the conjecture that some of these serous cysts may be of thymic origin is of interest (Fig 20 1.)

Thymic hypertrophy in infancy It is unwise to diagnose this condition except in the presence of firm radiological evidence Thymic asthma and status lymphaticus are no



(*a*)



(*b*)

Fig 20 4

(*a*) Radiograph of the chest in a child of 18 months showing broadening of the mediastinum
Although the mass projects to the right side the trachea is also displaced to the right and at operation for the relief of the severe compression it was the left lobe of the gland that was the main cause of the pressure (see text)

(*b*) Hypertrophied thymus removed for the relief of severe mediastinal compression
The right and the left lobes are pictured

longer accepted as clinical conditions and earlier attempts to remove these glands for the relief of symptoms are quite discredited (Keynes, 1946)

Broad mediastinal shadows seen in many infants are often due to enlargement of the superior mediastinal veins and vary greatly at different stages of breathing, being accentuated by the act of crying A true enlargement of the thymus (usually symptomless) can, however,

be demonstrated radiologically characteristically the lower border of the gland is separated from the mass of the heart with which it forms a typical angle or notch or overlies it like a jib sail (F H Kemp 1948) The onset and continuance of stridor and of severe dyspnoea in an infant with a radiological shadow of superior mediastinal enlargement does however justify the rare diagnosis of thymic obstruction under no circumstances should radiotherapy be employed * Most exceptionally an excision of the obstructing thymus is justifiable

A male infant aged 18 months was brought to the Children s Hospital because of frequent fits When he lay down severe cyanosis developed to be followed by a period of unconsciousness clearly the result of cerebral anoxia stridor was frequent He was a well-developed child with no obvious abnormality detected in the chest on physical examination A radiological examination (Dr Roy Astley) was carried out and the large mediastinal mass (Fig 20·4 (*a*)) detected. While awaiting a bed for admission to the hospital for possible radiotherapy he became seriously ill and unconscious His mother brought him to the hospital at once On arrival he had regained consciousness but was cyanosed with difficult stertorous and stridulous breathing The right chest was opened two hours after his admission through the classical lateral thoracotomy performed across the bed of the resected fifth right rib A huge enlargement of the thymus gland was obvious The right lobe was easily removed but the trachea remained obstructed and displaced to the right side by the left lobe which was readily resected (Fig 20·4 (*b*)) Histological examination of the tissue showed simple thymic hypertrophy and hyperplasia (Dr Baar) The post-operative recovery was satisfactory

Thymic tumours

The odd fascinating and unexplained association between thymic tumours and myasthenia gravis is underlined by the experience of Keynes (1955) who in 260 patients with myasthenia gravis found that 41 had tumours Thymic tumours do not all cause myasthenia The known association inaugurated the surgical treatment of myasthenia gravis initiated by Sauerbach in 1912 and thoroughly launched by Blalock (1937) in the United States of America and Keynes (1942) in this country Although Blalock was able to report promising results after removal of the thymus with true tumour formation Keynes with a large experience has described the progress in patients with thymic tumours after operative removal as unsatisfactory though the addition of preoperative irradiation has improved the prospects At the moment undoubtedly the best results after surgery in the treatment of myasthenia gravis are in those patients who have a simple thymus not necessarily enlarged but usually with an excess of germinal follicles

Pathology and clinical features of thymic tumours The confusing pathological picture is such that some writers say that only innocent thymomata cause myasthenia this is hardly acceptable as undoubtedly these tumours show local invasive characteristics and recur after removal Keynes (1955) in a most authoritative clinical account of these tumours discusses this problem in detail Usually there is a dense fibrous capsule around the tumour but invasion of the lungs and pericardium may occur If the tumour which is composed of abnormal thymocytes or epithelial cells or a mixture of the two (reticulo-epithelioma) causes myasthenia the patient is usually in the 30–40 age group has an acute severe disease and is often resistant to medical treatment As stressed by Keynes the tumour may only be seen by means of lateral tomography and should not be operated on until a very careful course of radiotherapy has been given Surgery in conjunction with radiotherapy has much improved the results

* From the United States has come evidence that radiotherapy to the thymus gland in childhood has been followed in a very significant number of patients by the development of cancer of the thyroid gland later in life

Thymectomy for myasthenia gravis. The indications for removal of the thymus and the assessments of the results in a disease that has a peculiar natural history of notable remissions are far from simple. Since the relationship between the disease and the function of the normal or abnormal thymus is poorly understood the choice of treatment by surgery rather than by prostigmine or its related drugs will depend on the comparison of results obtained by a rather empirical operation and those of a medically treated series.

Keynes (1949), reporting his results in 155 thymectomies, was able to assess the effects on 120 patients (10 patients had died post-operatively, 18 had tumours and were considered



(a) (b)

Fig. 20 5—Malignant thymoma in an infant

(a) The symptoms were dyspnoea and stridor. At thoracotomy a malignant tumour infiltrating the lung and pericardium was found. It was quite inoperable.

(b) The tumour consists of large cells in epithelial or syncytial arrangement with vesical and elongated nuclei. There are many binucleate or multinuclear cells and mitotic figures are frequent. (Dr H Baar)

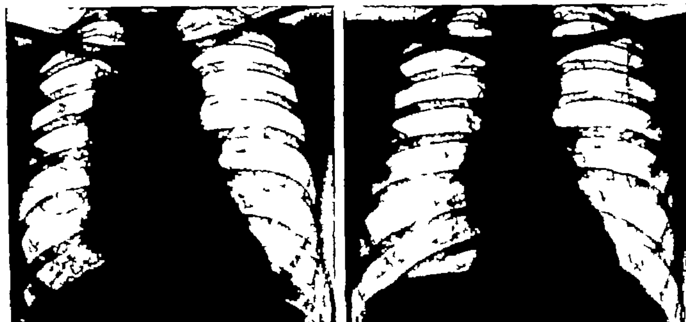
separately and 7 for a variety of reasons were not yet assessed). Of the 120, 39 (32 5 per cent) were well symptom-free and not taking prostigmine, 40 (33 3 per cent) were virtually well, but taking small doses of neostigmine, and only 9 per cent showed no improvement.

Kennedy and Moersch reported 87 patients with myasthenia gravis who were seen between 1915 and 1932, an era when prostigmine or surgery was not available. Thirty-four of the patients died in periods varying from 6 months to 22 years. Harvey (1948) further studied this series and found that 27 of the patients had complete remissions which for different periods lay between one month and 16 years. I am certain that thymectomy is now being requested by neurologists more frequently than up to 1952. The independent follow-up of Keynes' large series of thymectomies by Dr R T Ross showed that good results were obtained in nearly 70 of 100 studied patients. If the symptoms are not readily controlled by drugs surgery should always be considered.

The indications for surgery The selection will largely be in the hands of the physicians

who will withhold operation from patients with minimal or moderate symptoms well controlled by neostigmine If large doses of this drug do not enable the patient to lead a reasonable life and especially if the drug is producing unpleasant side-effects such as intestinal colic without improvement of the myasthenia, operation should be advised The idea that those patients who have been given neostigmine for a long period will not benefit from operation is doubtful and the best result in my own short series was in a patient who had received prostigmine or neostigmine for nearly ten years

There is a tendency to withhold operation in older patients over 40 years (Viets) but



(*a*) (*b*)

Fig 20·6

(*a*) Radiograph of the chest of a woman of 34 years with a rapid onset of severe myasthenia gravis.
(*b*) Radiographic appearances five weeks after deep X ray therapy
In spite of this striking result there was no improvement in the symptoms these however regressed rapidly after thymectomy At operation the tumour was malignant and had partly invaded the right lung. The patient is well six years later

Keynes believes that the age of the disease is more likely to militate against a good result than the age of the patient Probably the best surgical results are in the age group 20–30 with a short history of the disease but infants and children may do well * Griffin (1956) had an excellent result following an emergency thymectomy done on a patient in respiratory failure

Tumours of the gland as visualized by radiology are an indication for operation but Keynes (1949) advises a course of deep X ray therapy before operation and believes that the results after this combination are better than when operation alone is employed Considerable shrinkage of the tumour may follow deep X ray therapy but the symptoms of myasthenia may not be relieved In two of our patients a rapid decrease in the size of thymic tumours was followed by an aggravation of the symptoms of myasthenia

The size of the gland removed and its relation to the results In his last review Keynes is careful to point out that the glands removed are frequently no bigger than those found at the same age in people without myasthenia and that size bears no relation to the severity

* One undesirable side-effect of thymectomy in children may be the development of precocious sexuality This has happened in two of my patients.

course or prognosis of the disease. The outstanding difference in the myasthenic thymus is the consistency with which conspicuous lymphoid germinal centres appear in contrast to their rarity in the glands of other subjects and Viets (1950) reached the same findings.

The operation of thymectomy. *The approach.* Excision through an upper median sternotomy is preferable to a transpleural approach because it enables a complete thymectomy under direct vision to be carried out; through the median incision the chief anxiety, the securing and ligation of the thymic veins draining into the innominate vein, is overcome because the exposure is direct and the great vein is easily identified and cleared. The objection to a transpleural approach on the grounds that it increases the post-operative respiratory complications is doubtful and on three occasions I have opened the pleura accidentally during a trans-sternal thymectomy without any post-operative sequels of an unpleasant nature; such an opening will have no ill effects if all the air is withdrawn by an artificial pneumothorax apparatus after the closure of the wound and the full re-expansion of the lung proved by a radiograph taken before the patient leaves the theatre. The preference for the median approach is based on the good surgical access it provides; there is a place for the more formal thoracotomy transpleural approach when large thymomata have been disclosed on a pre-operative radiograph (Fig. 20.4).

Pre-operative measures and anaesthesia. The dose of neostigmine known to afford benefit is maintained right up to the time for operation; no purgative or enema is given as these exhaust an already weakened patient. Preliminary postural drainage exercises and education in the use of an oxygen tent are taught for some days before operation by the nursing and physiotherapy staff and the need for post-operative efforts at expectoration indicated, together with an explanation that assistance may be given post-operatively by the use of intratracheal or bronchoscopic aspiration. In our own series we have not experienced difficulty about post-operative collections of mucus in the bronchial passages and I think the routine " cough " discipline in a thoracic ward largely dissipates this fear. It is possible that over-dosage with neostigmine during the operation may be a cause of pulmonary oedema (Viets, 1950). The dosage in the theatre may be based on the following formula: 15 mg. of neostigmine bromide is the equivalent in effect of 0.5 mg. administered intravenously, and the appropriate dose can therefore be estimated. Atropine sulphate gr. $\frac{1}{100}$ is also given pre-operatively.

Anaesthesia is induced by pentothal, a very much smaller dose being required than in the usual type of thoracic case and is maintained by a gas and oxygen mixture. Curare is contra-indicated in view of the suggested biochemical basis of the disease in which a curare-like substance is thought to exist at the neuro-muscular junction. The essential anaesthetic requirements are a perfect airway and an adequate oxygen supply.

The operation. The patient is placed in the usual thyroidectomy position with a small sand-bag or flat pillow under the shoulder, the neck is extended and the head lowered as far as possible within the anaesthetist's requirement for providing a good airway. Local anaesthesia (0.5 per cent procaine in saline) is injected subcutaneously above and along the front of the sternum. The vertical incision to be made over the centre of the sternum reaches one inch into the neck. The transverse incision in the neck commonly advised is not necessary, provided through the upper end of the incision a clear view is obtained of the sternal heads of the sterno-mastoid muscle and the space of Burns; any veins joining the jugulars across this space are isolated, ligated and divided. A meticulous exposure of the curved upper border of the sternum is essential and by the combination of finger and pledglet dissection the posterior surface of the bone is cleared; portions of the infrahyoid muscles are divided.

The skin over the middle of the sternum is incised down to periosteum as far as the fourth costal cartilage bleeding is checked by the application of artery forceps to the divided edge of the pectoralis major muscle and these are placed close together and rolled outwards as in the manner employed in checking bleeding from the scalp by seizing the galea aponeurotica Large vessels are sealed off by applying the diathermy point to the artery forceps that have picked them up The sternum should be widely exposed the wound edges being firmly retracted after gauze pads have been placed under the retractors The fourth right costal cartilage is then exposed and its perichondrium elevated after the anterior aspect of this sheath has been incised it strips badly but every effort must be made to clear its posterior surface thoroughly so that a small Doyen s raspatory can be passed below it to maintain an intact pleura A small portion of the cartilage may be excised flush with its sternal junction the fourth left cartilage is dealt with in the same way Frequently however the lateral border of the sternum can be exposed sufficiently to allow of its transverse division without any resection of the costal cartilage

Working as close to the sternum as possible a curved Price Thomas elevator is used to clear it of the loose areolar tissue that lies between it the reflections of the pleura and the pericardium slowly a way is cleared until a curved metal instrument of the Adson elevator type can be passed from the bed of the resected cartilage to the corresponding site on the other side the sternum is then divided at this level by the Lebsch s chisel, Schumacker or Exner bone cutters A thin bladed osteotome is then introduced beneath the upper end of the divided sternum on each side and when the bone has been elevated the loose areolar tissue beneath, which is closely applied to the thin pleural membranes on each side is gently brushed aside by mops on long curved artery forceps It is easy to tear the pleura at this stage unless the greatest care is exercised. If this clearing is carefully but adequately done a complete freeing of the posterior surface of the sternum is readily achieved and is combined with a similar attack on the back of the bone at the upper end. The sternum is then free from all mediastinal tissues and can be readily divided by the Schumacker or Exner s bone-cutting forceps or by a mallet and osteotome Bleeding from the cut oozing surface of the vascular sternum is checked by the application of Horsley s bone wax

Once the sternum has been freely divided a pair of double blunt hooks are used one on each side to lift and separate the divided segments through the gap so created a single Tuffier retractor is inserted and when this is screwed open a wide exposure of the superior mediastinum is obtained This space is covered by a relatively strong layer of fibro-fatty tissue which forms a real sheath to the thymus gland at first it may be mistaken for the gland itself It is freely opened after being held up between two pairs of artery forceps and entered by the use of fine curved scissors The opened fascia when brushed aside displaces the pleura laterally with it but the pleural membrane on each side comes very close to the mid line and should be pushed aside by moist pledglet dissection before the actual opening is made into the fibro fatty envelope

When this sheath has been widely opened the yellowish pink thymus gland is seen and its extent varies greatly the two lower poles always reach well down on to the pericardium and they should be elevated after being grasped in light mosquito-artery forceps and peeled off the sac by pledglet dissection No large vessels are met until the upper poles of the glands are being secured The gland is slowly lifted upwards until the innominate vein is seen on its deep surface As the dissection proceeds at this stage the greatest care must be taken to identify the thymic veins there are always two branches occasionally more and they enter as separate trunks of some size into the innominate vein They are seized divided and ligated and then the upper poles usually in the shape of two thin horns

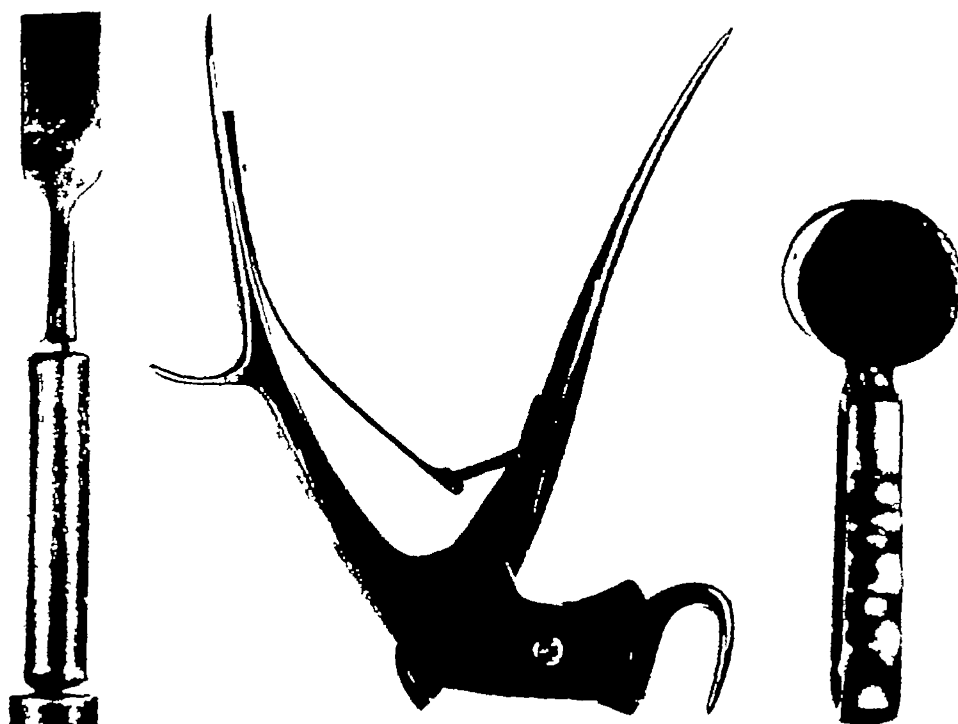


FIG. 207.—Exner's bone cutting forceps, hammer and broad-bladed osteotome, useful instruments for sternal division

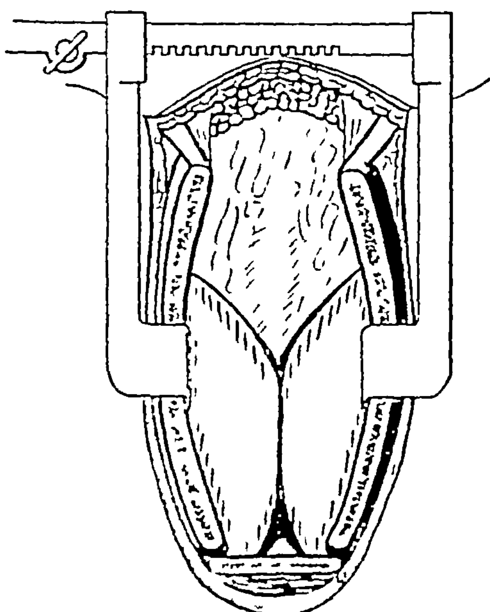


FIG. 208.—Upper medial sternotomy

The areolar tissue above the two pleural sacs covers the thymus

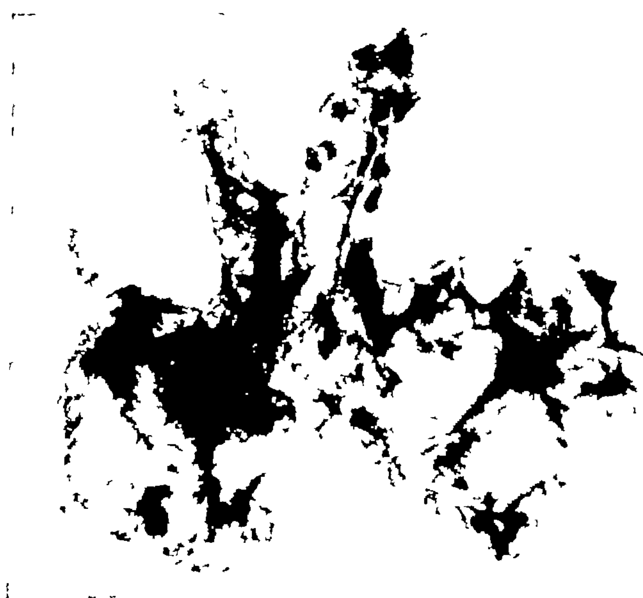


FIG. 209.—Thymectomy for myasthenia gravis

There is a tumour in the left lobe of the thymus. Histologically it was a lymphoepithelioma. Note the bilateral nature of the gland with two upper and two lower poles

are followed up to the neck where they appear to run into the lower poles of the thyroid small arteries are present at this level and require ligation. The thymus gland strips easily from its mediastinal bed and apart from possible injury to the thymic vein and the pleura there are no hazards When the bed is completely dry the wound is closed the divided sternum is readily approximated if the shoulders on each side are held slightly upwards The divided sternum is then lashed together with two silver wire sutures passed through drill holes made on each side with a brace and bit interrupted silk sutures are passed through the thicker fibrous tissue that spreads out into the pectoralis major muscle and are sufficient to secure and maintain approximation



FIG 20-10.—A large thymus removed from a child of 1_ years with severe myasthenia gravis (natural size)

The neck wound is closed in the usual way after the platysma has been sutured by 0000 catgut Michel s clips may be used in the neck skin but the sternal portion is better closed by interrupted black silk sutures A small drain is left in the neck wound for 24 hours

Post-operative treatment The bronchial tree is aspirated dry at the close of the operation and further neostigmine is given by subcutaneous injection the patient is returned to an oxygen tent for the first 24–48 hours The main post-operative care is to ensure a clear tracheo-bronchial tree and the usual measures to achieve this are taken

Thoracic goitre

Intrathoracic goitre is not always as simple from the diagnostic and excisional point of view as is frequently believed Many goitres have substernal prolongations which provide no difficulty during thyroidectomy as they are dislocated upwards with ease if the plane of dissection is in the true peri thyroid space Even those of large size that reach far down into the thorax to overlie the pericardium are readily delivered but all thoracic goitres do not follow the common pattern and every thoracic clinic receives patients who have been referred as malignant mediastinal tumours and may have been subjected to deep X ray irradiation. All intrathoracic goitres do not have a connection with the gland in

the neck, though most of them do nor do all intrathoracic goitres enter the chest in front of the innominate vein, trachea and oesophagus, a few proceeding down behind the clavicle to enter the thorax and assume a position deep to these structures

Finally in analysing the unusual from the common, thoracic goitres do not necessarily draw their arterial blood supply from the neck through the inferior thyroid artery, exceptionally they have an arterial supply from the aorta or from one or other subclavian artery

The diagnostic and surgical approach should not be oversimplified though most of these goitres can be removed safely through a collar incision, occasional ones require a trans-sternal or even a transpleural approach The surgeon, quite exceptionally, must be prepared to split the sternum do a thoracotomy posteriorly or enlarge the neck incision into a sternum-splitting operation

Diagnosis The onset of compression symptoms affecting the trachea and producing stridor in a known goitrous patient, makes for an easy diagnosis which radiology of the thoracic involvement will confirm the radiological examination will disclose the site of the mass and the extent and type of tracheal distortion Rarely the intrathoracic goitrous prolongation will lie behind the trachea and the oesophagus this I have seen four times and two of these patients have been recorded (Tomkinson, 1951) Keynes (1950) has reported two in the posterior mediastinum and Sweet (1949) describes six in a lucid and full account of thoracic goitre

The difficult diagnosis is concerned with those patients who at their history taking fail to disclose that at a younger age they had a goitre that disappeared gradually such a slow disappearance may have been completely forgotten until they arrive at hospital because of dyspnoea, stridor and the other symptoms of upper thoracic compression This may be instanced by two short histories

Mrs D, aged 50, was referred for opinion because of increasing dyspnoea and stridor, associated with gross distension of the veins of the head, neck, and arms for six months the symptoms had progressed relentlessly and she could only walk 20 yards The voice had altered in pitch and tone and there was some hoarseness A diagnosis of malignant mediastinal tumour had been made and she was sent for deep X-ray therapy The radiograph (Fig 20 11) shows a mass to the right of the mediastinum without the clear lower border usually, but not invariably, associated with a retro-sternal goitre it lay nearly in front of the trachea which was displaced to the left

On close questioning she disclosed that from the age of 15 to 25 she had had a very full neck of which her family used to make fun by the time she was 30 the neck was entirely normal, and the disappearance was attributed to the use of iodine ointment Through a collar incision an intrathoracic goitre was removed easily

Mrs T, aged 39, suffered from repeated coughs and pain in the right chest a pleural effusion had developed six months before after a pyrexial illness No actual evidence of tuberculosis was obtained but this was considered to be the cause of the effusion Because of repeated attacks of respiratory obstruction and the radiological evidence of a tumour arising on the right side of the mediastinum she was referred for surgical treatment (Dr Brian Taylor) Radiological screening of this patient showed that a portion of this ovoid tumour lay behind the trachea and the oesophagus Because of the central mass of calcification, which was erroneously regarded as being a plaque of bone, the pre-operative provisional diagnosis was "dermoid cyst" (Fig 20 12)

The right chest was opened by a posterolateral thoracotomy through the bed of the fifth rib As soon as the tumour was exposed the diagnosis was obviously that of intrathoracic goitre, as the tissue was typically thyroid in appearance the blood vessels came from above and application of ligatures to them from this thoracic approach was difficult The tumour, in spite of its posterior position, would have been more easily removed through a cervical incision

When told, on the day after operation, that the "tumour" was a goitre, the patient surprised us all by saying that she had wondered where the goitre which she was conscious of in adolescence had gone to! Such a history obtained pre-operatively in combination with the calcification which

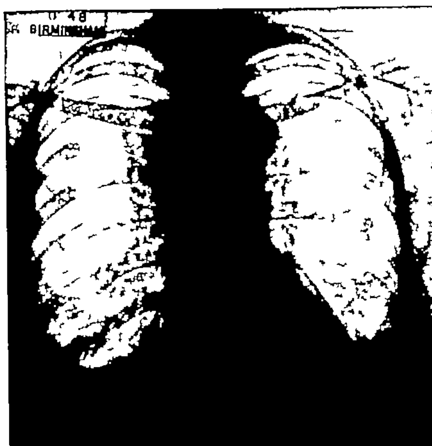


Fig 20-11.—Not a typical picture of retro-sternal goitre because of the indefinite outline of the lower edge

A very clear history of a goitre that had "disappeared" was of considerable help in the diagnosis (see text).



Fig 20-12.—Radiograph of a woman of 39 years showing a mass in the region of the right side of the superior mediastinum with an area of calcification in it

The lateral radiograph showed it to be well behind the line of the trachea and oesophagus; the pre-operative diagnosis was not thoracic goitre (see text).

is so often seen in long-standing thyroid adenoma would have enabled a correct diagnosis to be made

Ectopic intrathoracic goitre

Occasionally a thyroid may develop in the mediastinum without any connection with the cervical gland and with an independent blood supply (aberrant or ectopic mediastinal goitre) Such tumours may be diagnosed as aneurysms or true mediastinal neoplasms

Mrs E, aged 49, had suffered from attacks of dyspnoea of some severity for 8 years At another hospital on two occasions bilateral cervical thyroidectomy had been done for a large colloid goitre, the second operation being for a recurrence of the mass two years before her admission to hospital When the radiograph (Fig 20 13 (*a*)) was taken she had considerable stridor and could only sleep in a propped-up position There was a considerable recurrence of the goitre in the neck on the left side

At operation, the neck was exposed and the large left lobe of the thyroid completely removed There was no connection between the gland and the mediastinal mass which could not be felt through a retro-sternal dissection the sternum was therefore split and a large mass of thyroid removed from its position overlying the pericardium the blood supply to this ectopic thyroid tumour in the chest was from two branches which arose directly from the aorta

Differential diagnosis of thoracic goitre Apart from lymphadenoma and secondary involvement of the space by extensions from malignant bronchial tumours, intrathoracic goitre is the commonest cause of a space-occupying tumour of the superior mediastinum

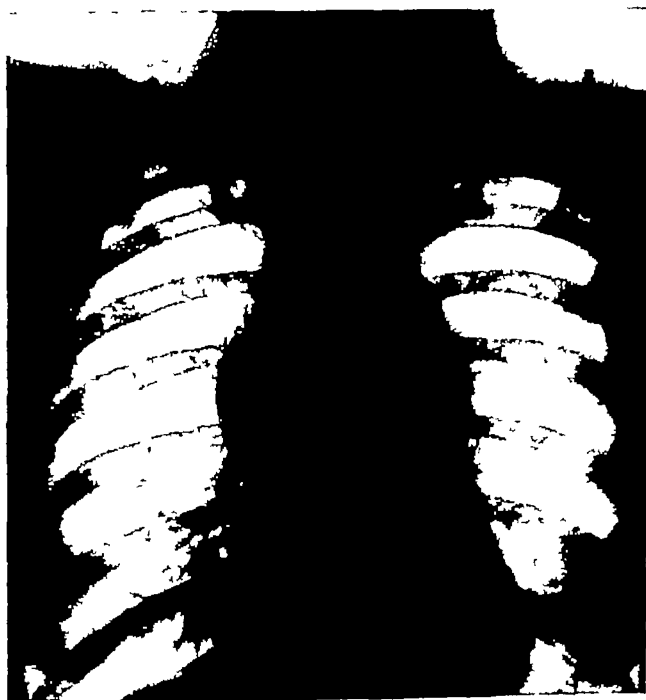


Fig 20 13 (*a*)—Radiograph of the chest showing a large mass in the mediastinum (see text)

The symptoms it causes, unless there is the complicating factor of thyrotoxicosis, are those of superior mediastinal compression with dyspnoea, stridor, engorgement of the neck veins and persistent cough, as the most striking Hoarseness is sometimes a symptom and may be attributed wrongly to a malignant invasion of the recurrent laryngeal nerve Dysphagia is most rare



Fig 20-13 (b) —Photograph of thyroid tissue removed.

The mass on the left was the hemi-lobectomy specimen removed through a neck incision, that on the right being the mediastinal goitre which had no connection with the cervical goitre and received an independent blood supply from the aorta.



Fig 20-14



Fig 20 15

Fig 20-14 —A typical radiograph of an intrathoracic goitre causing stridor

A goitre was palpable in the neck of a woman of 70 The thoracic portion reached down to the level of the sixth rib posteriorly

Fig 20 15 —The operative specimen shows a typical intrathoracic prolongation which was readily delivered through a neck incision.

Mistaken diagnoses include aneurysm of the aorta, or innominate artery, Hodgkin's disease neurofibroma (which is almost universally sited posteriorly), dermoid cysts, thymic tumours, a dilated oesophagus in patients with severe cardiospasm and mediastinal abscess

The radiological features are usually typical

The tumour may be seen on both sides of the mediastinum or may deviate to one side alone The outlines are usually clear though often irregular if there are false adenomata present The trachea is typically displaced backwards and to one side, and a continuation of the shadow above the clavicle is usually seen Calcification is an occasional finding If there is radiological difficulty in establishing the diagnosis radio-isotopes are of value after these have been absorbed the Geiger counter may be useful in showing that the mass contains thyroid tissue (Tomoff, 1950)

Surgical treatment of thoracic goitre. If thyrotoxicosis is present the patient should be treated by bed rest, iodine and sedatives as a pre-operative measure thiouracil may be dangerous as the increase in the size of the gland in its confined quarters might precipitate or aggravate tracheal obstruction As already stated the goitre can be delivered quite easily from a neck approach if the peri-thyroid space is carefully exposed and entered If the goitre cannot be delivered because of its size (which is due to the "adenomatous" enlargement often aggravated by the pathological complication of necrosis, cyst formation, haemorrhage and calcification), the centre of the goitre may be removed to decrease the bulk of the tumour which can then be delivered easily In exceptional instances the sternum may require division and instruments should be at hand for this I have had to split the sternum twice in fifty operations for thoracic goitre The retro-oesophageal goitre can be delivered from the neck without the need for thoracotomy in most instances, though division of the sternum is sometimes essential for safe resection (Keynes, 1950)

Dermoid cyst or teratoma

The commonest site for these "tumours" apart from the ovary is in the anterior mediastinum usually they contain all three germinal elements The condition is not common Harrington with a vast experience of mediastinal surgery had 16 personal cases up to 1937 Rusby (1944) in a complete review analysed 251 examples I have only operated upon seven and have seen three others Usually they have a simple pedicle containing vessels from the parietal pericardium and if uninfected, without bronchial connection and have not undergone malignant change, are well encapsulated and easily removed They do not always arise in the anterior mediastinum and I have removed one from between the diaphragm and the right lower lobe of the lung, and one from the left posterior mediastinal space

Pathology and natural history The solid teratomatous tumour may show early signs of malignant transformation as in the testis or ovary , the large cysts with smooth walls and sebaceous contents probably do not develop malignant tendencies The cyst of this type has a lining of skin supplied with the usual secreting glands and there may be teeth or bony elements present They cause their effects by pressure The solid dermoid tumour is probably a different condition from the outset , the term "cyst" is not truly applicable as it is essentially a solid complex mass composed of derivatives of all three germinal layers often containing cartilage, bone, gastro-intestinal and respiratory elements and nervous tissue These tumours are rare

Symptoms and diagnosis Symptoms will only develop as a result of pressure, malignant





Fig 20-16 Fig 20-17

Fig 20-16 —Large dermoid cyst in the typical anterior position.

Severe compression symptoms causing frequent fainting attacks brought the patient for examination. At operation a large cyst full of sebaceous material and hair was removed. There was complete relief of symptoms and patient is well three years later

Fig 20-17 —Large dermoid cyst of the anterior mediastinum with a tooth seen

The tumour is so large that the chest wall is bulging.



(a)



(b)

Fig *0-18

(a) Solid teratoma of the mediastinum

There as severe dyspnoea The tumour is occupying a large amount of space in both sides of the chest It was removed ith complete relief of symptoms (Dr O Brenner case)

(b) The tumour after removal through a wide left-sided thoracotomy

The tumour was so big and bulky (*4 cm) that considerable difficulty was experienced in deli ering it. Histologically there as no malignant change and the patient i well seven years after operation.

transformation or infection symptomless dermoids may be detected in routine or mass radiography reviews, the large ones, however, cause pressure effects such as dyspnoea, cough, pain and palpitations The chest wall may bulge as the result of very large cysts (Fig 20 17), and the heart be grossly displaced Dullness on percussion may be detected on one or both sides of the sternum The cyst may rupture into a bronchus causing expectoration of sebaceous greasy material, followed later by purulent sputum the result of secondary infection developing from the eroded bronchus

Differential diagnosis They require differentiation from thoracic aneurysm and para-mediastinal empyema The absence of tracheal tug and of the other signs and symptoms

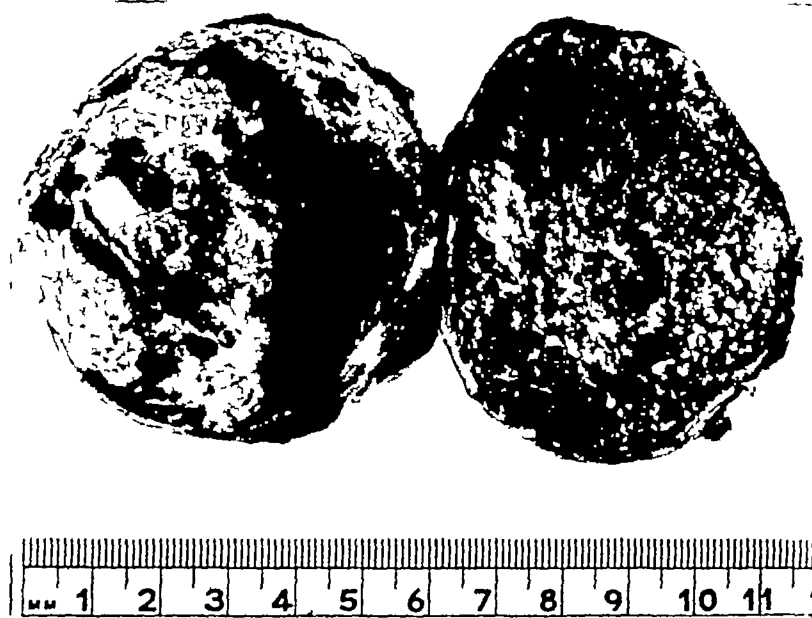


Fig 20 19—Photograph of operative specimen of a dermoid cyst containing sebaceous material

of aneurysm (especially the cardiac ones) will help in the clinical differentiation A more exact analysis is possible by the use of angiocardiography Para-mediastinal empyema is usually associated with a quite different antecedent history in which cough and pyrexia may have been prominent features The diagnostic exclusion of other conditions such as bronchiogenic cysts, lipoma, and other rare encapsulated tumours may be impossible, but these can be removed through the incision that would be selected for operation upon a mediastinal dermoid The differentiation from a retro-sternal goitre is, however, important, as the latter requires usually a cervical approach for its excision The radiological appearances of retro-sternal goitre are usually quite different

Large cysts in the inferior mediastinum may so obscure the heart shadow that a diagnosis of pericardial effusion may be made this error is not made if the apex beat is palpable in a displaced position which is usual, but the tumour may be so large that the apex cannot be accurately located (Fig 20 18)

Radiological appearances Typically the cyst has a smooth circular outline which broadens out into a flat base at the origin of the mass from the mediastinum · this flat base is seen on the lateral view The wall may be calcified The shadow can be separated from the cardiac silhouette on the screen the chief difficulty is experienced when the cyst has caused compression of the lung or has even occluded the bronchus, for then the outline of the cyst is not clear, merging with the shadow cast by the consolidated or atelectatic

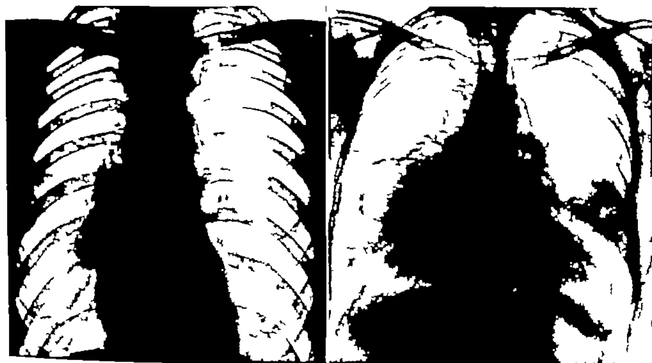
lung tissue Transmitted pulsation of the heart beat to the tumour is common on screening and this may lead to an erroneous diagnosis of aneurysm

Treatment Except in the face of exceptional contra indications removal should be advised to avoid the dangers of thoracic compression malignant degeneration cardiac disturbance and secondary infection The approach is by a large transpleural thoracotomy the side containing the largest projection of the tumour being selected The mediastinal pleura over the tumour is opened widely and the cyst enucleated from its false sac Usually there is a well-developed layer of areolar tissue and as this is stripped the pedicle which may be single or multiple is defined the vessels in it are not often large The chest is usually closed with drainage for 24 to 48 hours

If the cyst has been drained previously the operative removal may present formidable difficulties and malignant change with spread to the mediastinum may make this impossible

Pleuro-pericardial cysts (spring water cysts)

Thin walled serous cysts lined by endothelium are occasionally found adjacent to the pericardium or in the cardio phrenic angle either anteriorly or posteriorly and at operation



(*a*) (*b*)

Fig 10-20

(*a*) Radiograph of pleuro-pericardial cyst
(*b*) Radiograph of a woman of 30 complaining of severe dyspnoea showing a large shadow overlying the cardiac one at operation this was a very large pleuro-pericardial cyst clearly interfering with the ventilation of both lungs.

appear to rise from the parietal pericardium less commonly they develop in the superior mediastinum or are sited just above the diaphragm A similar type of cyst is found attached to the parietal pleura or the diaphragm (d Abreu 1937) Their chief importance is from the diagnostic aspect Rarely do they cause pain or pressure symptoms and an increasingly large number are being diagnosed in symptomless patients who have undergone miniature mass

radiography examinations Because of the increasing use of exploratory thoracotomy for most patients with " tumours", as measures designed to excise all possibly malignant lesions, and because so many of the intrathoracic swellings ultimately cause pressure symptoms, a few of these cysts are removed annually in most centres As mentioned elsewhere Barrett has indicated that because of their laxity considerable deformation of their shape is usual after the induction of an artificial pneumothorax and this physical sign might well support a conservative abstention from surgery The cysts have a simple endothelial lining to which occasionally is attached thymic tissue (Thompson) It is only possible to suggest that they are congenital in origin it is not surprising that the complicated embryological process of pleural, pericardial and diaphragmatic development should be associated with " inclusion " cyst formations They may be associated with pericardial defects, why they sometimes cause pain is difficult to explain

The diagnosis from the radiological features is by a process of exclusion or as the result of an exploratory thoracotomy for a thoracic tumour Their removal is simple and they readily strip from the pericardium

POSTERIOR MEDIASTINAL TUMOURS

Carcinoma

Involvement of the posterior mediastinum by gross lymphatic enlargements secondary to bronchial carcinoma is common, this enlargement is often detectable radiologically with or without a barium swallow Occasionally such involvements are out of all proportion to the size of the primary tumour in the lung and an exploratory thoracotomy may be done because the mass has been regarded as an encapsulated innocent tumour

Neurogenic tumours

The clinical diagnosis and excision of these tumours is simpler to describe than their complicated pathology, they represent an important group of tumours seen in children and adults Many more have been excised than have reached the literature and their detection has been increased since the use of mass radiography They represent the most important group of tumours met with in the posterior mediastinum Arising from nerve elements they show features of fibrous and nervous tissue which may arise from the central or sympathetic nervous systems tumours of sympathetic origin are commonest in children and may be ganglio-neuromata or sympathetico-blastomata In the usual tumour as seen in adults fibrous tissue elements predominate, hence the common name " neurofibroma ", or the less commonly used term " perineural fibroblastoma "

When malignant change takes place (in 41 per cent of cases according to Blades, a figure regarded by many as surprisingly high) the tumour usually has the characteristics of a sarcoma In my own experience of 27 of these tumours 3 have been malignant Typically these tumours enlarge to ovoid shapes which grow out into the hemithorax occasionally they burrow into the vertebral foramen and may produce pressure on the spinal cord Symptoms when present are from pressure on adjacent structures such as the nerve of origin (Fig 20 24), the spinal cord (Fig 20 30), or the bronchus (Fig 20 27) Pressure upon the overlying ribs or involved thoracic vertebrae may produce a combination of distortion decalcification and sclerosis Although essentially developing in the posterior mediastinum neurofibroma may quite exceptionally be elsewhere, I have seen one in the



Fig 20·21 —Parietal tumour overlying the 8th and 9th right ribs in the axillary line

Histologically the removed tumour was typically that of neurofibroma

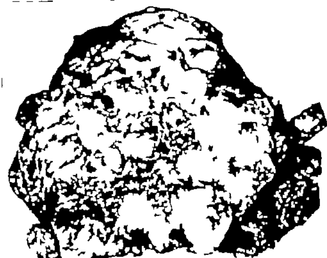


Fig 20·22 —Sarcomatous change in a neurofibroma from a patient with generalized von Recklinghausen's disease



(a)



(b)

Fig 20·23 —An encapsulated benign tumour showing areas of vascularity and haemorrhage

The elements of the tumour are fibrous tissue and nerve fibres. The characteristic arrangement of cells in a neurinoma is seen in some parts (a) × 100, (b) × 400 (Prof. J W Orr)

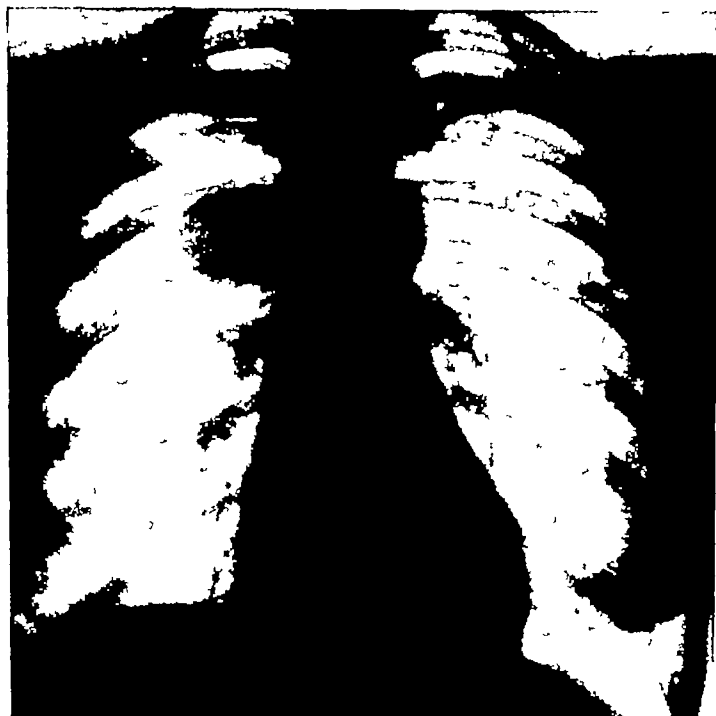
anterior part of the chest overlying the pericardium (d'Abreu, 1947) and three arising from intercostal nerves well away from the posterior part of the chest

Large masses may develop in the chest of patients with generalized neurofibromatosis (Von Recklinghausen's disease) These tumours may be in the posterior mediastinum involving at times many intercostal nerves, or they may enlarge anywhere in the line of the intercostal nerves . their tendency to sarcomatous change is well known

The pathology of these tumours is difficult and varying histological reports state that some are true neuromata with a fibrillary structure resembling that of peripheral nerves others undoubtedly are tumours primarily of the nerve sheath (Schwannoma, perineural fibroblastoma), and a compound variety is described in which neural and fibrous elements are intermingled

Sympathetico-blastoma

This tumour which develops in children in the abdomen or thorax is a neuroblastoma consisting of immature cells or behaving quite unpredictably though usually as a malignant





(a) (b)

Fig 20 24

(*a*) Radiograph of the chest of a woman of 40 years

The X-ray examination was carried out because of pain in the line of the 6th intercostal nerve

(*b*) Neurofibroma removed at operation

The intercostal nerve is seen entering and leaving the tumour

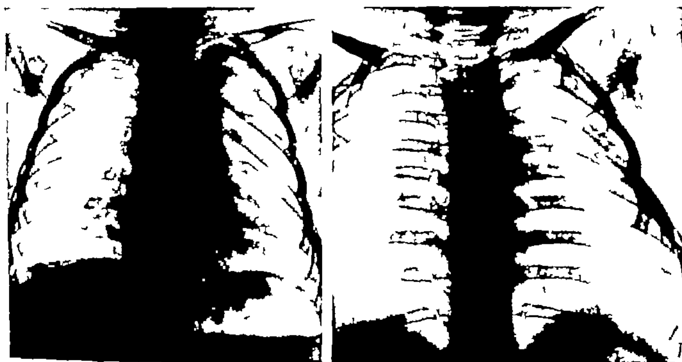
state The administration of vitamin B_{12} may be of value in producing maturation and disappearance of cells Radiologically they often contain calcium

Fig 20 25 is a radiograph of a child of six months who suddenly developed a complete paraplegia of the legs with sensory loss up to the nipple line the tumour in the left chest was submitted to exploratory thoracotomy An invasive tumour involving the left lung and the pericardium was seen to have its main pedicle of attachment posteriorly in the mediastinum Removal was impossible and the parents were given a hopeless prognosis No radiotherapy was employed A year later, the child was seen she was in perfect health and the paraplegia had completely

disappeared A penetrating radiograph (Fig 20·25 (*b*)) indicates marked retrogression of the tumour and the upper lobe of the lung appears to be free from infiltration. The ultimate prognosis is quite unknown but she is well six years after the exploration

Ganglio-neuroma

This is commoner than the sympathetico blastoma its natural history is equally unpredictable it may retrogress or become malignant depending on the fate of the neuro blastomatous cells It usually has a wider base of origin than the neurofibroma and this gives a characteristic radiological appearance Although all surgeons are not in agreement I feel that their excision is indicated Because of this extensive basal attachment excision may be a difficult procedure



(*a*) (*b*)

FIG 20·25

(*a*) Radiograph showing tumour of the left side of the superior mediastinum involving the lung—biopsy at thoracotomy malignant sympathetico-blastoma

The child had paraplegia. (Dr H. Baar)

(*b*) Radiograph of the same child four years later

The child is well and the paraplegia has disappeared (see text).

Diagnosis and treatment of thoracic neurogenic tumours Some of these tumours are symptomless being discovered on routine mass radiography whether free from symptoms or not an exact diagnosis is required if possible as surgical opinion favours excising neuro fibromata because of the dangers of later compression or of malignant change The commonest symptom is pain which if present radiates along the line of the affected inter costal nerve the large tumours may cause dyspnoea and cardiac symptoms and the picture of lung infection may be present if the tumour has caused atelectasis of part of the lung from pressure and inflammatory adherence of the capsule of the tumour to the lung may develop

The radiographs (Figs 20·26 20·27) are those of neurogenic thoracic tumours that have been removed by operation their histories are interesting The child (Fig 20·26) was referred to



Fig 20 26



Fig 20 27

Fig 20 26 —Radiograph showing a large tumour in the left chest

A large ganglio neuroma was removed from this child of 8 years Histology revealed a typical ganglio neuroma The child is alive and well eight years later (Dr A G Watkins' case)

Fig 20 27 —Neurofibroma of the right chest associated with an inflammatory change in the right upper lobe of a man of 20 years



Fig 20 28



Fig 20 29

Fig 20 28 —Radiograph of a woman of 39 years

There was increasing dyspnoea for years, sudden stridor and extreme respiratory obstruction At emergency operation a neurofibroma was removed (see text)

Fig 20 29 —A radiograph of a small tumour proved histologically to be a neurofibroma after excision

The symptoms were pain in the back and a diagnosis of tuberculous abscess had been made elsewhere

Dr A. G Watkins as suffering from asthma for which she had been treated for years the apex beat of the heart was displaced to the right of the sternum and fainting attacks were common, these and the asthma have disappeared completely since the removal of the tumour

Fig 20-27 is the radiograph of the chest of a young man of 20 who had three attacks of upper lobe pneumonia after the last attack the chest was X rayed with the appearances shown there is an obvious opacity of the right upper lobe of the lung beyond the edge of the tumour At thoracotomy an area of chronic suppurative pneumonia was resected together with the tumour he has remained at full work for over four years

Mrs S (Fig 20-28) had suffered from increasing dyspnoea regarded as asthma for three years She was admitted urgently to the Queen Elizabeth Hospital with severe stridor and considerable cyanosis an emergency thoracotomy was done and a large neurofibroma removed with immediate relief of symptoms

The radiological pictures usually show an ovoid tumour which on the lateral projection lies posteriorly but projected well forward

Before reaching a large size these tumours may be more rounded in shape (Fig 20 29) especially when sited at the apex of the chest The overlying ribs may be forced somewhat apart or show signs of distortion and sclerosis at the rib edges. Rib changes even of the most marked degree must not be regarded as evidence of malignant change in the tumour

Treatment Surgical removal should be advised for the reasons given a wide trans pleural thoracotomy is done the pleura overlying the tumour widely incised and reflected The blood supply is from the posteriorly placed intercostal vessels and the tumour should be cautiously mobilized before these are clamped off as rough handling may cause them to bleed near their aortic origins If sarcomatous change has taken place the surrounding ribs may be removed together with the tumour but the operation may well have to be abandoned if the malignant extension is considerable The removal of a ganglio neuroma may be very difficult as a simple pedicle is not available The tumours are not radio-sensitive except in a few examples of malignant sympathetico blastoma in children

Dumb-bell tumours

The spread of the tumour into the spinal cord through the intervertebral foramen is not common but paraplegia may be the first symptom

Mrs. L. L. was referred to Prof Brodie Hughes with paraplegia this had been slowly developing for a year she was sent in urgently because of the sudden onset of retention of urine The radiograph of the chest showed the appearances typical of neurofibroma radiological



Fig 20-30 —The removed neurofibroma (8 cm.) The large intraspinal projection i to the right.



(*a*)



(*b*)

FIG 20 31

(*a*) Bronchiogenic cyst in a man of 28 years

Symptoms were those of pain in the upper chest and of chronic cough without sputum A bronchiogenic cyst was removed through a postero lateral thoracotomy

(*b*) Cartilage in relation to a bronchiogenic cyst (H E × 150)



FIG 20 32 —Lower congenital accessory cyst with a secondary developed opening into the left lower lobe

This is not a true bronchiogenic cyst though probably of the same origin namely a duplication of the foregut At lobectomy a large accessory artery was found coming through the diaphragm to supply the cyst (see Chapter I [illegible])

studies of the spinal column showed a great widening of the intervertebral foramen at the ninth thoracic level As an emergency procedure a thoracotomy was performed the neurofibroma had a wide-necked prolongation into the spinal canal which it was impossible to deliver through the chest wound Prof Hughes did a laminectomy and the tumour was removed in one piece (Fig 20 30) The intraspinal prolongation was unusually long The patient made a complete recovery from the paraplegia

In the treatment of these dumb bell tumours two-stage operations should be avoided

Bronchiogenic, gastrogenous and enterogenous cysts

Since the lungs develop as out-buddings from the primitive foregut duplications (Baar and d Abreu 1950) within the thorax are to be expected Misplaced areas of foregut tissue are usually situated in the posterior mediastinum and may develop into large cysts (Fig 20-31 (a)) at a later stage in embryological development sequestrated portions of bronchial elements likewise may grow in the posterior mediastinum and be quite separate from the lung itself to form what are usually described as bronchiogenic cysts These are not to be confused with the cysts found usually in the region of and attached to the lower lobes of the lung in association with an abnormal blood supply These mediastinal cysts contain fluid of varying appear ance and in their walls may be typical bronchial mucous membrane (Fig 20 31 (*b*)) if the cysts are bronchiogenic and elements of the foregut if they are gastric or enteric They may cause symptoms by pressure effects upon the lung bronchi or oesophagus quite exceptionally the heart is disturbed by large varieties Peptic ulcer or erosions may develop in the gastric type and lead to haemorrhages Bronchiogenic cysts are usually high up in the mediastinum often with fibrous connections to the area of the tracheal bifurcation it is tempting to think that these displaced portions of bronchial tissue had their origin in the obliteration of the tracheo oesophageal groove and represent minor deviations from the gross abnormality of tracheo-oesophageal fistulae Cysts lined by bronchial epithelium are sometimes found above the bifurcation to one or other side of the trachea they are a cause of stridor in infants and easily overlooked in the differential diagnosis of that state (see " emphysema Chap 21)



FIG 20-33 —An enterogenous cyst causing displacement of the oesophagus.

The pre-operative diagnosis was neuro fibroma or possibly an enteric or bronchiogenic cyst At operation the cyst had a pedicle that reached up t the bifurcation of the trachea

The surgical removal of these cysts may be diffi cult if they have developed fistulous communications with adjacent structures such as the trachea bronchus or oesophagus such communications must be deliber ately divided and the openings into the viscera closed by careful interrupted sutures reinforced if possible by pedicled pleural flaps Once infection has developed the finding of surgical planes may be formidable Duplication cysts of the oesophagus are described on page 435 Interesting accompanying abnormalities may be a cervical hemi vertebra and a deformed or absent radius

The radiological appearances are those of a tumour in the posterior mediastinum displacing the trachea or the oesophagus

Miscellaneous mediastinal tumours

A wide range of tumours has been recorded, usually in publications dealing with one or few cases lipoma, fibroma, xanthoma, chondroma, hydatid cysts and lymphangioma (Harley, 1950) or cystic hygroma, may be mentioned The lipomata may be of large size developing from the pleuro-pericardial fat and often late in producing symptoms, their point of origin is almost invariably in the anterior mediastinum. They may have intrathoracic and extrathoracic portions More and more of these tumours are being recorded, following exploratory operations that have been advised after the detection by mass radiography of unexplained shadows They are by no means as simple as their name suggests. Heuer and Andrus (1940) collected 28 examples of mediastinal lipoma of these 13 were untreated by surgery and died Their evil reputation is due to the fact that they may attain a huge size and occasion gross intrathoracic compression effects which produce cough and choking attacks, pain, dyspnoea and cyanosis They do not show lobulation on the radiograph, but are usually less opaque at their periphery than at the centre

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PART VI

SOME MISCELLANEOUS CONDITIONS

CHAPTER 21

SURGICAL ASPECTS OF PULMONARY EMPHYSEMA

Emphysematous changes in the lung may be bilateral unilateral lobar or segmental a good deal of confusion exists in the whole group which ranges from large air cysts and diffuse cystic changes seen in infancy to the fully developed state of bullous formation in adults with generalized hypertrophic emphysema Cystic disease of the lung though occasionally congenital is frequently acquired It is often impossible even after full histological examination to decide whether these cysts are congenital or acquired but at all events they can be separated into two classes (a) those derived from the bronchial tree and (b) those of alveolar origin (Moersch and Clagett 1947) Surgery may be indicated for the mechanical embarrassments produced by emphysema and giant cysts and especially for the complication of chronic or recurrent spontaneous pneumothorax secondary to such conditions It is not possible to discuss in detail the physiopathology of these lesions which are described under a wide range of terms such as pneumatocele giant air cysts cystic or bullous emphysema and emphysematous blebs The term compensatory emphysema is applied to the enlargement of other lobes that follows permanent collapse or resection of other areas of the lungs and has been discussed elsewhere especially in the chapter on lung neoplasms with reference to the changes that follow total pneumonectomy

The assessment of patients with emphysema who have serious accompanying lesions such as bronchial neoplasm tuberculosis and bronchiectasis before major surgical operation is contemplated is of obvious importance and has been discussed in Chapter 2 As the condition of true emphysema is irreversible pre-operative tests of lung function are not to be disregarded if major surgery is being considered Patients with evidence of right ventricular heart stress are unlikely to survive excisional operations as they are already anoxic with a low vital capacity diminished arterial oxygen saturation and the other features that accompany the associated pulmonary hypertension

If patients with emphysema are subjected to surgery constant watch must be kept for the earliest signs of right-sided heart failure the onset of cyanosis a raised pulse rate elevation of the jugular venous pressure the presence of capillary pulsation and faintness of the heart sounds are important clinical features The main therapeutic lines are directed to any associated lung infection and to the relief of anoxia if there is bronchial spasm adrenalin and aminophylline are used Temporary tracheotomy reducing the dead space air and permitting easy suction of secretions is in increasing use If there is any cardiac irregularity digoxin is indicated After thoracotomy this type of patient may remain or become comatose due to carbon dioxide retention Because of their apparent well being e.g. good colour and good pulse while under oxygen therapy the danger may be overlooked

They require artificial ventilation via an intratracheal tube or a tracheostomy combined with efficient carbon dioxide absorption by a soda lime canister

Pathological emphysema (chronic hypertrophic type)

Both lungs, one lobe, or a segment of a lobe may be affected by emphysema, obstructive, compensatory or congenital in origin the term indicates over-inflation and dilatation of the alveoli and distal parts of the bronchioles If compensatory emphysema is excluded for the moment from consideration, the condition is a progressive one in which the elastic tissue of the alveoli atrophies, recoil is lost and eventually destruction of the alveolar walls leads to the formation of large conglomerate air sacs, blebs,* bullae or giant cysts which may become so large that by their pressure effects they impair the efficiency of the neighbouring lung tissue The function of the lung becomes progressively impaired, because although air enters the distended alveoli and pulmonary blood circulation is maintained, the exchange of gases between the two is seriously impeded

Bilateral acquired emphysema

Emphysema may result from frequent repeated and sudden rises of intrabronchial pressure when the expiratory phase is increased against a closed glottis, as in the coughing of chronic bronchitis and asthma, during these attacks the terminal bronchioles widen and the air pressure within them is increased suddenly when the glottis closes and air becomes imprisoned in the lobules, if there is scarring or oedema of the small bronchioles, their calibre is further decreased by the normal constriction that accompanies expiration, so that a valvular mechanism develops and entraps air in the alveoli The distension of individual alveoli may be partly relieved by the air drift from the pores in the alveolar wall sacs to adjacent lobules (the collateral ventilation of van Allen and Lindskog, 1931). Not only should this mechanism relieve tension but it would prepare the way for the further air entry of oxygen into the over-distended alveoli

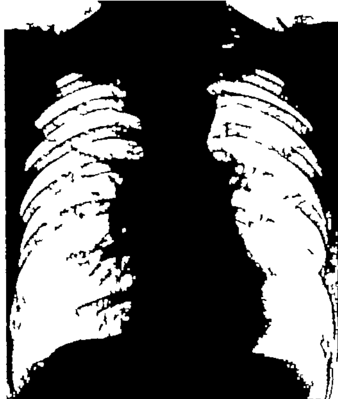
Emphysema developing as a result of bronchial or bronchiolar disease, as after scarring from old tuberculous disease, may be segmental, lobar or generalized with bullous formation Bullous and bleb formation is a common cause of spontaneous pneumothorax, and is often responsible for a "spontaneous" pneumothorax complicating an artificial pneumothorax induced as treatment for pulmonary tuberculosis but quite apart from this severe complication, the emphysematous area may cause significant symptoms severe enough to demand surgical treatment of the affected area This will be considered later

In generalized emphysema the chief defect in the pulmonary physiology depends on the loss of lung elasticity, the lung parenchyma becomes over-distended and cannot collapse properly in expiration, so that the residual and functional residual air becomes increased with consequent lowering of the reserve and complemental air volumes The chest wall movements are poor especially as the diaphragm becomes depressed and flattened and the intrapleural pressure becomes less sub-atmospheric The tension effects of the entrapped air and the need for more work to be done to ventilate the lungs is more likely to produce conscious dyspnoea than the mechanism postulated by the Hering-Brauer reflex

Obstructive emphysema

Incomplete obstruction of a bronchus, lobar or segmental, may cause a temporary emphysema, occasionally the first indication that a tumour, a foreign body or tuberculous process is present It is unusual to see patients with carcinoma at this stage as most of them only come for investigation when complete bronchial obstruction has caused collapse

* Blebs were defined by Miller (1927) as subpleural collections of air which followed the rupture of distended alveoli bullae represented collections of entrapped air within the lung parenchyma Both are quite different from congenital lung cysts



(*a*)



(*b*)

Fig 21 1

(*a*) Radiograph showing emphysema of left lower lobe associated with a left para hilar mass. There is absence of vascular marking when compared with right lower lobe Symptoms were of dyspnoea and haemoptysis and bronchoscopy showed tumour partially blocking the lower lobe

(*b*) Pneumonectomy specimen emphysema of the diaphragmatic surface of the lung

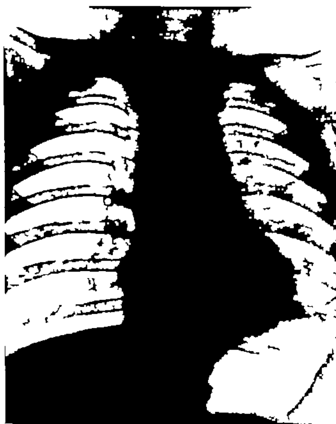


Fig 1 —Child of 19 months admitted with dyspnoea and slight pyrexia : note emphysema of right lung during inspiration At bronchoscopy a piece of nut was removed from the right main bronchus. (Mr Keith Roberts.)

after the preliminary obstructive emphysema Exceptionally emphysema may be due to extrinsic pressure on a bronchus from a tumour, gland, or mediastinal mass Both lungs may be emphysematous as the result of persistent tracheal obstructions

A mediastinal obstruction may affect one bronchus more than the other and when operations are in progress for unilateral emphysema in infants this should be remembered

An infant was admitted to the Children's Hospital, Birmingham, with gross dyspnoea and stridor the left chest was bulging and left-sided emphysema was well seen on the radiograph (Fig 21 3), which also shows considerable downwards displacement of the diaphragm A bronchiogenic cyst in the posterior mediastinum behind the tracheal bifurcation with its main extension behind the left bronchus was the cause of the obstructive emphysema

Partial obstruction of a bronchus may be due also to inflammatory bronchial disease in bronchitis or tuberculosis In the latter disease the tuberculous endobronchitis not



FIG 21 3—Gross obstructive emphysema of the left lung in an infant, due to a mediastinal bronchiogenic cyst disclosed at operation

The cyst was pressing firmly against the trachea Compare with case illustrated in Fig 21 6

infrequently causes complete collapse of an upper lobe and partial obstruction of the lower lobe, which becomes grossly distended as a result of the incomplete occlusion of its bronchus and because it undergoes compensatory emphysema to fill in the thoracic space previously occupied by its now atelectatic companion An especially important cause of obstructive emphysema involving a lobe or whole lung is the extrinsic pressure of large glands in children with a primary tuberculous complex , bilateral emphysema may be seen if there is compression of the lower end of the trachea and stridor usually accompanies this state Because such emphysema is often the precursor of irreversible atelectasis of a lobe or lung, Dillwyn Thomas has indicated the need at times for excision of such masses of glands (see Chap 10).

Localized emphysema, as the result of the great tension developing in the emphysematous cysts, may compress and cripple the remainder of the lobe or lung These giant cysts can be treated, occasionally by phrenic nerve paralysis but more commonly by local,

segmental or lobar resection often these large cysts may be opened and the bronchial communication closed by sutures

Compensatory emphysema

When the intrathoracic space on one side has been diminished because of disease or surgical removal of one area the remaining healthy tissue will expand to avoid the reduction of space-occupying lung this commonplace finding in a chest X ray where there is translucent emphysema of an upper lobe is often the first indication that collapse of the lower lobe is present On the left side of the chest the atelectasis of the lower lobe as it lies behind the heart may be overlooked if the associated emphysema of the upper lobe is not noted



Fig 21·4 —Emphysema at both bases.

There is an obvious collapse of the right lower lobe the partial collapse of the left lower lobe is concealed by the heart shadow Bronchography demonstrated bronchiectasis in both collapsed lower lobes.

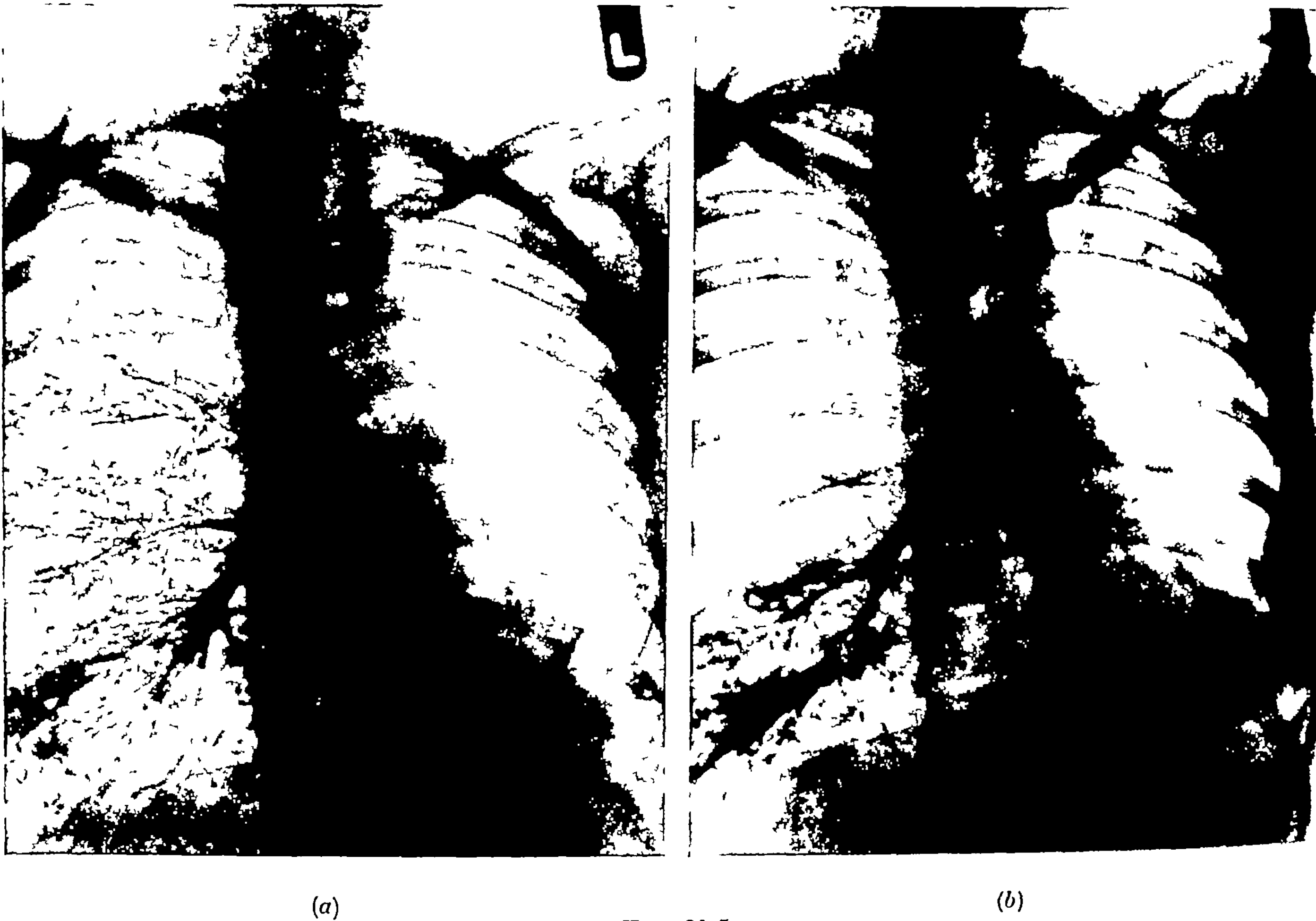
If a diseased part of a lung which has lost alveolar function recovers rapidly e.g pneumonia massive temporary collapse of a lobe the emphysema will disappear but in long-standing disease the over-distension of the aerated portions remains permanent

If the whole lung of one side is congenitally absent or deficient (agenesis) or has been surgically removed, the contralateral lung over-distends hypertrophies and pushes the mediastinum over to fill in the dead space of the empty pleural cavity (Fig 21 5)

The dangers of compensatory emphysema passing on into true pathological emphysema cannot be discounted although lobectomy and pneumonectomy have been performed for many years we still lack evidence as to the ultimate condition and function of the remaining lobe or lungs Pathological evidence based on the inspection of lungs after pneumonectomy and the autopsy reports on patients who have succumbed years after excision operations shows that the passing of compensatory emphysema to hypertrophic emphysema with loss of elasticity bullous formation and obstruction of the peri alveolar capillaries is a slow

process. If the excisions are done at a young age the emphysema probably remains truly compensatory and it is possible that the remaining lung or lobes may show true hyperplasia. This applies also to the sound lung in patients with agenesis. The surgical correction of compensatory emphysema after pneumonectomy by thoracoplasty, pleural filling with non-absorbable material, phrenic avulsion, and pneumo-peritoneum has been discussed in Chapter 12.

Cournand and others (1950) have published an important paper on pulmonary circulation and alveolar ventilation—perfusion relationships after pneumonectomy; in addition to measurements of the lung volumes, the maximum breathing capacity, the distribution



(*a*) (*b*)

FIG. 21.5

This woman of 39 years complained of dyspnoea which was not sufficient to prevent her from carrying out all her household duties and she had four healthy children.

The heart was so displaced to the left and posteriorly that the maximum cardiac impulse was in the scapular line. The whole of the right lung is grossly emphysematous and its middle lobe fills the left hemithorax.

The bronchograms demonstrate agenesis of the left lung.

of tidal air throughout the lung, ventilation and of arterial blood oxygen saturation under varying states of activity, they added observations made from cardiac catheterization and the measurements of partial pressures of carbon dioxide and oxygen in the arterial blood. They studied 16 patients after pneumonectomy carried out for a variety of pathological states and at widely differing ages. A mild degree of pulmonary hypertension developed in all after mild exercise, and this may be severe under strenuous tests; but they pointed out that electrocardiographic studies did not indicate right ventricular hypertrophy in these patients. If pneumonectomy was followed by distension of the remaining lung, thoracoplasty was advisable; but evidence of distension was by no means inevitable in the absence

of thoracoplasty and a thoracoplasty which caused a severe scoliosis in itself could be followed by pulmonary dysfunction

Compensatory emphysema as an aid to cavity closure in pulmonary tuberculosis

The idea that cavities close as a result of complete occlusion of the cavity-draining bronchus is based partly on the assumption that the lung tissue around the disappearing cavity is healthy enough not only to re-expand but to develop compensatory emphysema The valvular mechanism present in the bronchus draining tuberculous tension cavities is either changed into a complete block or becomes fully patent both in inspiration and expiration the cavity may close rapidly and this process is aided by the over-distension of surrounding healthy alveoli

Congenital causes of emphysema

Congenital causes of emphysema as distinct from true intrapulmonary cysts lined by bronchial epithelium may be associated with agenesis of a lobe or lung (Fig 21 5) with deficient cartilage formation in a lobar bronchus (Fig 21 6) or with congenital bronchiolectasis or alveolar dysplasia (Fig 21 6)

A few patients of the following type have been seen at the Children s Hospital Birmingham

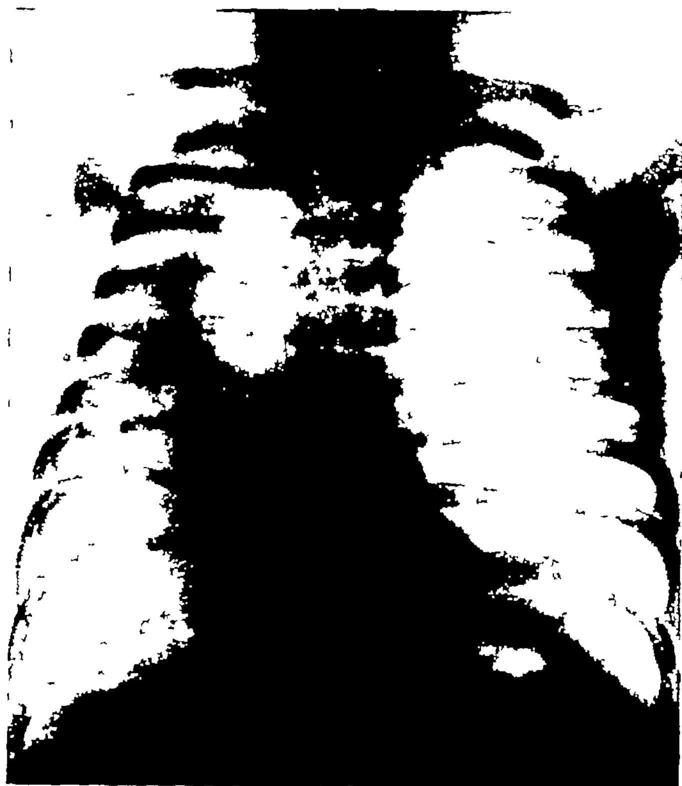
A. S a female infant had suffered from periodic attacks of dyspnoea since birth When first seen in August 1947 at the age of three months she was underweight and dyspnoeic the apex beat was displaced to the right and the left chest was bulging and tympanitic on percussion The radiographic appearances (Fig 21 6 (*a*)) were startling with a grossly emphysematous left upper lobe which had produced pressure collapse of the left lower and of the right upper lobe with great displacement of the mediastinum In the following two years existence was precarious In August 1949 the radiological condition was unaltered and surgery was regarded as offering the only hope of relief.

A lipiodol bronchogram (Fig 21 6 (*b*)) revealed a normal right bronchial tree a small but normal left lower lobe and an emphysematous left upper lobe into which lipiodol would not enter although a bronchial stump was present A left thoracotomy was performed and as soon as the pleural cavity was entered the left upper lobe grossly distended and emphysematous ballooned out of the wound it was removed by dissection lobectomy (Fig 21 6 (*c*)) The bronchus consisted of fibrous tissue only with a few scattered areas of cartilage As soon as the anaesthetist increased the intratracheal pressure the lower lobe re-aerated and two months later it almost occupied the complete left hemithorax. The child has had no further dyspnoea and has developed normally

This type of congenital emphysema may be associated with congenital heart disease

Another type of emphysema in infancy is represented by a rare group in which the terminal bronchioles open into defective alveolar tissue and they may be regarded as congenital bronchiolectasis and alveolar aplasia The following history represents an example of this group

C B an infant of a few days was admitted in extreme dyspnoea and cyanosis The radiographs of the chest (Fig 21 7) revealed an advanced degree of emphysema of the right middle lobe The remainder of the right lung and the upper lobe of the left lung were compressed In the hope that the condition was due to cartilage deficiency of the right middle lobe bronchus a thoracotomy was carried out immediately the chest was opened the middle lobe bronchus bulged out of the wound The distended lobe was removed but unfortunately the infant died without any relief having been afforded Dr Baar reported on the histology of the middle lobe as follows Middle lobe of right lung 9 × 6 × 1 5 cm in size The lobe presented the appearance of acute emphysema and in addition there were subpleural vesicles of interstitial emphysema On dissection, cystic spaces, up to 4 mm in diameter were found. Histological examination revealed dilatation of respiratory bronchioli alveolar ducts and alveoli There was generalized emphysema





(*a*) (*b*)

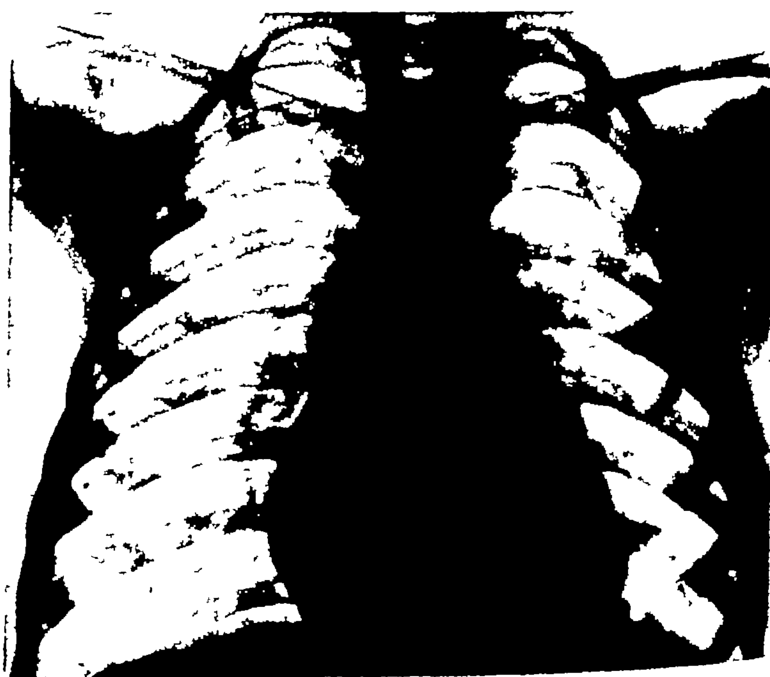
Fig 21 6

(*a*) Radiograph of infant aged 3 months showing gross emphysema of left upper lobe with pressure collapse of the left lower and right upper segments

(*b*) Lipiodol bronchogram at the age of 2 years

Gross emphysema of left upper lobe There is no filling of the left upper lobe bronchus



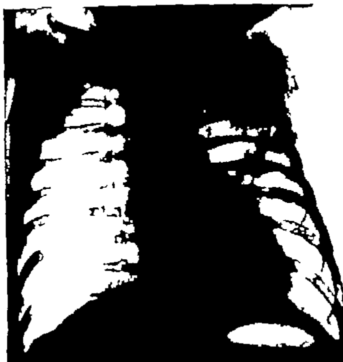


(*c*) (*d*)

Fig 21 6

(*c*) The emphysematous left upper lobe (13 cm) lobectomy specimen

(*d*) Radiograph of the chest a year after left upper lobectomy

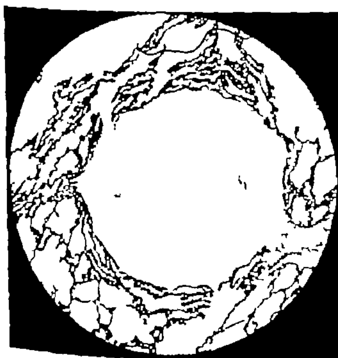




(a) (b)

Fig 21

(a) Congenital emphysema of right middle lobe
Postero-anterior radiograph of chest.
(b) Lateral radiograph showing distended right middle lobe





(c) (d)

Fig 21 —Histological appearances of excised middle lobe (see text)

and, in addition, larger cystic spaces, the walls of which had the character of alveolar walls and scattered small solid areas in which there was a failure of differentiation of alveoli

Acquired giant emphysematous cysts

Localized emphysema may cause serious symptoms and disability because the tension in the " cysts " may cripple the remainder of the lung or lungs, as in the case of the children just described. but more usually it is in patients with bilateral emphysema that large bullous cysts occasion exacerbations of dyspnoea, these air cysts may follow a slit-like tear into the wall of an adjacent bronchus which allows air to enter the huge sac in inspiration but leaves it entrapped in expiration when the opening becomes valvular The rupture of emphysematous blebs and bullae accounts for some examples of spontaneous pneumothorax When the lobe or lung is occupied by smooth thin-walled " cysts " without evidence of lung or pleural inflammation a congenital origin may be possible, although inflammatory obliterative bronchitis is the common cause once the condition is present the continued distension of alveoli and the rupture of one distended alveolus into another may produce such tension that the bronchiole supplying the affected area may itself give way to leave a slit-like opening into an area of bullous formation (Allison, 1947)

Operative attacks on such giant emphysematous cysts may be required when the enlargement is causing grave dyspnoea in an already crippled patient or when they rupture to cause a chronic spontaneous pneumothorax (Brock, 1948, Brewer, 1950) Dugan and Samson (1951), Capel and Belcher (1957), have described their experiences for this condition in which considerable relief was provided by surgical measures

Indications for surgery in emphysema

Many patients with bilateral or unilateral emphysema though partly incapacitated can lead normal lives, these patients rarely come for surgical attention but in a few instances the progressive enlargement of emphysematous blebs or bullae may cause spontaneous pneumothorax or severe dyspnoea As already mentioned, in recent years surgical attention has been directed to a small group with large air-containing cysts which by their high tension and because they provide large dead-space reservoirs cause a completely disabling dyspnoea These cysts are usually multiple, but may be single Quite often the apparently " single " cyst is the dramatic feature of a patient's radiograph and distracts attention from the generalized emphysema

The physiological aims in surgical treatment are to relieve local tension effects or to decrease the residual air and so diminish the inadequate ventilation of alveoli At first sight it would appear to be foolish to sacrifice any lung tissue, but in the resection of grossly emphysematous tissue it must be remembered that not only is the resected tissue non-functional, but it is often an actual embarrassment to the respiratory physiology In emphysema the pathological process has produced great destruction of elastic tissue and of the alveolar walls, these latter become distended (because they cannot recoil owing to elastic deficiency) and rupture into each other to produce gross air cysts

In direct attacks upon local areas of emphysematous disease the surgeon can only hope to correct (and that in quite exceptional cases) the defective gaseous composition of the blood and to decrease the amount of residual air In large tension cysts with a valvular mechanism which comes into play in expiration, this impediment can be overcome by removal of the cyst or cysts or by obliterating the valve-like mechanism or in a few cases by interruption of the phrenic nerve

The larger the communication between the air cysts and the bronchi the less is the

disturbance of function correspondingly surgery is less frequently required The chief disadvantage to the patient is over ventilation of lung areas that are poorly perfused with blood The dead space air is increased In patients with unilateral cystic disease pneumonectomy is indicated chiefly for the relief of infection but may improve lung function by removing a large area of lung tissue associated with very inefficient gas exchange After operation although the total lung volume will be diminished the maximum breathing capacity improves The surgical problem in this group is really that of the treatment of bronchiectasis and is judged by the same standards

Air cysts with poor or intermittent communication with the bronchus These provide a far more crippling effect than those with wide open communications Dyspnoea and asthmatic attacks are important features Severe ventilatory insufficiency is due to interference with the bellows action of the lung which does not deflate on expiration and the *tension within the cyst may be high Lung volume and the maximum breathing capacity* are reduced. Spirography discloses evidence of expiratory obstruction and air trapping the oxygen uptake is diminished

If the remainder of the lung tissue is not too emphysematous great relief may be afforded to these patients by excisional surgery or by the obliteration of the cystic area by suture after they have been opened and their valvular openings into the bronchi obliterated Physiological studies have been made to show the improvement that follows surgery in this group of patients (Baldwin, Harden Green Cournand and Richards 1950)

Surgical obliteration or excision of large air cysts of the lung can play an important part in relieving grave dyspnoea in emphysematous patients Surgery is confined to breath less patients in whom a quarter or more of the lung field is occupied by the cyst and in whom the affected lung is contributing less than half the total respiratory function this can be estimated by bronchospirometry or by the method of non-spirometric measurement of differential lung function described by Armitage and Taylor (1956)

Non bronchospirometric measurement of differential lung function

At the end of bronchoscopy under local anaesthesia air samples are taken during expiration from within each main bronchus and at two different levels in the trachea By estimating the respiratory quotient from these different samples the variations in function in the lungs can be estimated.

To illustrate the value of bronchospirometry the following case can be outlined

D G a man aged 47 complained of progressive dyspnoea the radiograph shows a large air cyst of the right upper lobe producing compression of the middle and lower lobes There is also considerable emphysema of the left lower lobe The findings from bronchospirometry (Dr D J S McIlveen) were as follows

D G Aged 47

	Right Lung	Left Lung	Total
Respiratory rate	11 breaths/minute		
Tidal volume	384	598	982
Inspiratory capacity	844	1,242	2 086
Expiratory capacity	211	322	533
Vital capacity	1 055	1,568	2 623
Minute volume	4 220	6,580	10,800
Min O_2 uptake	117	182	299
Ventilatory equivalent	3 600	3 620	

	Right Lung	Left Lung	Total
Temp correction			
(Spir) V C = 3,080 = 89 per cent			
V C = 2,750			
Oxygen uptake per cent	40	60	
Ventilation per cent	39	61	
Vital capacity per cent	40	60	
Inspiratory capacity	41	59	
Expiratory capacity	40	60	
Type of tracing very fair			
Position of catheter correct X-ray check			

Remarks Consistent with a non-functional, non-ventilatory, space-occupying air cyst in right lung

Surgical obliteration of this cyst was therefore indicated and carried out with great relief of dyspnoea

The Surgical Measures Through a postero-lateral thoracotomy the lung is exposed usually in addition to the large air cyst the remainder of the lung will show varying degrees of emphysema To conserve as much respiratory tissue as possible lobectomy is not

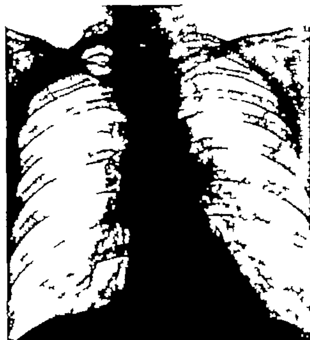


Fig 21 8 —Chest of a man of 47 with severe dyspnoea
Note large air cyst of right upper lobe For details see text

employed the cyst is opened widely and all bronchial openings into it are oversewn by fine silk and the whole cyst obliterated by appropriate sutures which make use of the redundant cyst wall which is infolded The chest is closed with two water-sealed intercostal drainage tubes

Another example is illustrated by the following

A man of 48 with a long history of chronic cough had recently become so disabled that he had to abandon his occupation as a 'bus driver A radiograph of his chest (Fig 21 9) shows a huge air cyst of the right upper lobe and generalized emphysema of the left lung Respiratory quotient studies (Dr A B Taylor and Dr G Armitage) showed that most of the lung function was being carried on by the left lung Thoracotomy was carried out , when the chest was opened,



(a)



(b)



(c)



(d)

Fig 21 9

(a) Pre-operative radiograph of a man of 48 with bilateral emphysema and a giant air cyst of right upper lobe

(b) Post-operative film six months after obliteration of bronchial openings into the cyst which was then deflated. The right lung is less emphysematous than the left. For clinical description see text

(c) Appearances at thoracotomy the distension by air of the upper lobe is seen

(d) The herniation of the cyst that followed an increased pressure in the cyst produced by the anaesthetist.

the left upper lobe tended to bulge out into the wound when the anaesthetist increased the pressure of gases flowing through the intra-tracheal tube an astonishing herniation of the lung occurred, showing the tension effect produced by full inspiration The massive air cyst was opened and slit-like tears in several small bronchi opening into it were sutured and the upper lobe reconstituted by obliterative sutures The remainder of the lung was seen to show emphysema The lung rapidly re-expanded The post-operative radiograph shows that the right lung now is less translucent than the left Respiratory quotient studies six months later showed that the right lung now has as much function as the left The clinical condition showed considerable improvement with great decrease in dyspnoea

Spontaneous pneumothorax

In most instances this takes the form of one single attack (simple spontaneous pneumothorax) about 60 to 70 per cent develop in non-tuberculous patients The complication develops in patients without obvious pulmonary disease (30 to 40 per cent) and the remaining group have a wide range of lesions including emphysema, asthma, bronchitis, tuberculosis, bronchiectasis, neoplasms, and staphylococcal lung abscess In the tuberculous group adhesions are often present and this is especially noteworthy in the patients who develop a spontaneous pneumothorax into a therapeutically induced artificial pneumothorax (the tuberculous cases often develop fluid, a quite exceptional finding in the non-tuberculous group)

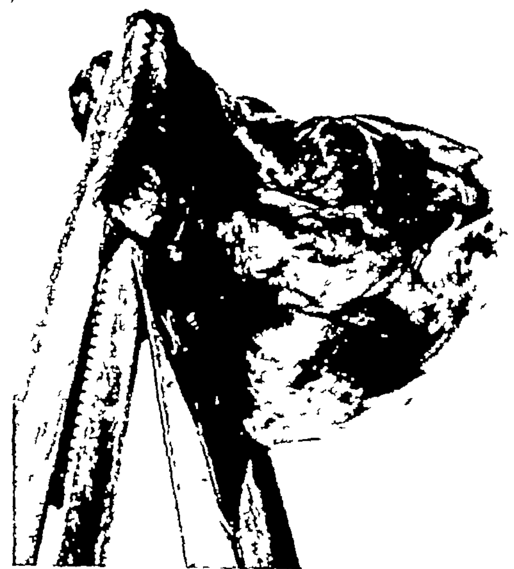


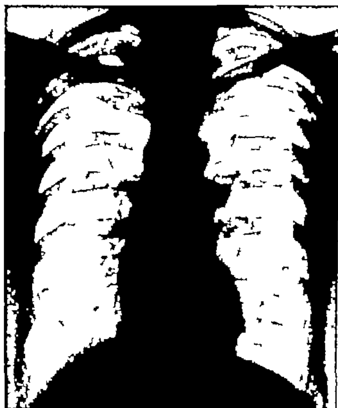
FIG 21 10—A small area of bullous formation resected from the apex of the right lung in a man of 22 who had suffered several attacks of spontaneous pneumothorax The remainder of the lung was completely normal

From evidence obtained at thoracoscopy, adhesions are often absent in patients with normal lungs or emphysematous lungs or when congenital cystic disease is present An important point is that spontaneous pneumothorax developing in the absence of serious pulmonary lesions is usually seen in a younger age group than when it complicates lung disease and that this benign group is far commoner in males Sudden exertion of a violent nature may be apparent in the history of the condition, which is diagnosed by the acute onset of pain and dyspnoea, associated with a tympanitic note on percussion, with possible displacement of the mediastinum and a characteristic radiographic appearance But a less dramatic type exists in which the diagnosis is made during a routine radiography The result of treatment by conservative measures is satisfactory in a large group , aided by withdrawal of small quantities of air if dyspnoea is present, and absolute bed rest, the lung usually re-expands in two to four weeks. Occasionally the collapsed lung becomes obstructed by intrabronchial secretions in these circumstances bronchoscopic aspirations may lead to rapid re-aeration

Surgical measures are indicated in the group of recurrent or chronic spontaneous pneumothorax, which will be considered below If the radiograph in the patient with a benign spontaneous pneumothorax reveals no pulmonary or pleural lesion, thoracoscopy is not necessary , if a spontaneous pneumothorax complicates a therapeutic pneumothorax and adhesions were seen on the radiograph before the leak developed, thoracoscopy for the division of the adhesion is indicated , division of suitable adhesions not only prevents the risk of a chronic pneumothorax, but may stop the formation of pleural effusion It is not

uncommon at such operations to note that the lung has torn at the pulmonary base of an adhesion. In nearly all the patients in this group who have been thoracoscoped subpleural blebs in areas of old lung disease are seen and usually the pneumothorax should be abandoned





(a) (b)

Fig 21 11

(a) Radiograph to illustrate a spontaneous pneumothorax with total lung collapse
(b) Radiograph two weeks later Air had been aspirated on two occasions.

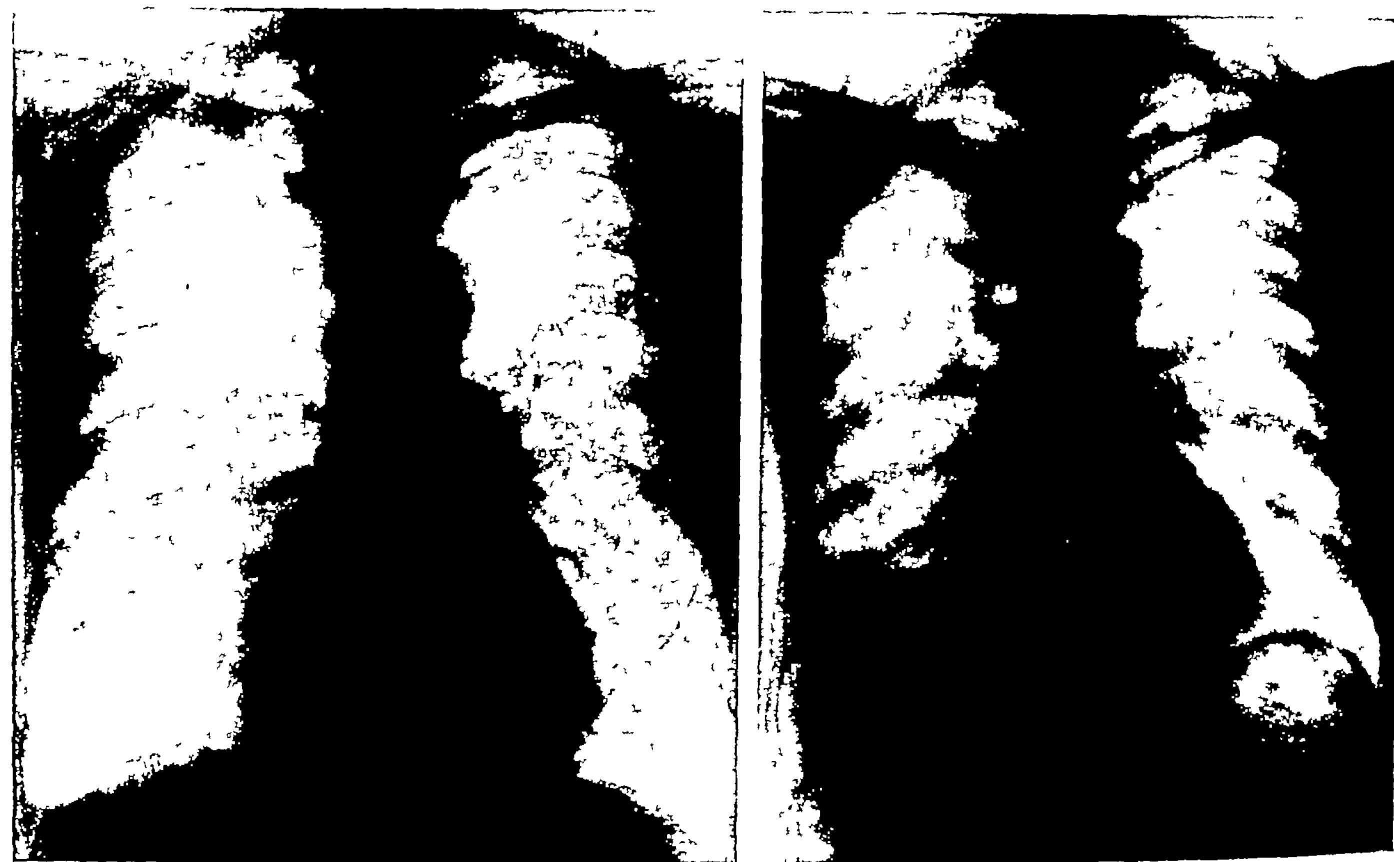
Chronic or recurrent spontaneous pneumothorax

The lung in these patients may remain collapsed for many months (15 months in 46 cases published by Brock) and the disability is severe and crippling if not treated adequately If re-expansion has not taken place within four to six weeks a full investigation in which thoracoscopy is essential is indicated because almost without exception the condition can be corrected.

In the largest published series of recurrent and spontaneous pneumothorax Brock (1948) found that persistent leak of air into the pleural cavity was noted in 25 patients with emphysema (12 with emphysema 13 with bullous emphysema) 8 in asthmatics with emphysema and bronchitis 15 times in association with small bullae mostly at the apex and in 11 patients with large solitary bullae or congenital cystic disease The incidence of bilateral recurrent or spontaneous pneumothorax is by no means insignificant as Brock studied 15 bilateral alternating cases and 8 in which both sides were involved simultaneously

The need for adequate treatment The patient with recurrent pneumothorax is at a grave disadvantage from a social and economic point of view The dread of recurrence and the handicaps imposed by advice that compels a regime of extreme quiet are heightened by the

ever-present danger of a spontaneous pneumothorax on the other side the patient with a chronic persistent pneumothorax is usually a permanent or semi-invalid. In distinction to the group who suffer only one pneumothorax, the benign simple type, the recurrent or chronic group include many people with underlying lung disease, the cause of the complication itself, and this pathological basis indicates that the further loss of respiratory function is serious Chronic spontaneous pneumothorax is, moreover, far commoner in the age group over 30 when respiratory reserve is less elastic and adjustable and severe dyspnoea



(*a*) (*b*)

FIG 21 12

(*a*) Bilateral emphysema with a right chronic spontaneous pneumothorax in a man of 52 years
He was severely dyspnoeic and orthopnoeic The middle and lower lobes are actively collapsed by the pressure of the positive pneumothorax and the upper lobe is grossly emphysematous and occupied by large bullae

(*b*) Three weeks after thoracotomy
Three large giant emphysematous bullae of the upper lobe were opened all had bronchi with slits in them opening into the "cysts" The bronchial tears were sutured and the cysts locally excised and obliterated by suture Lung re expansion was rapid and the dyspnoea greatly improved

often reflects the complication of collapse added to a frequently pre-existent bronchitis and emphysema The patient is usually very thin with a poor physical capacity for work

Investigation and treatment The demand for a full diagnostic technique is supported by the need for as accurate an assessment as possible of the underlying disease The history of asthma (perhaps now no longer in its true form) and the physical and radiological examination will often present a picture of emphysema of the general or bullous type invading one or both lungs The radiological examination of the pneumothorax must be scrupulous, for at times the differentiation of this from a huge, giant tension of the lung may be difficult, the danger of such an error is that a needle introduced into a supposed

pneumothorax may puncture the cyst possibly producing a fatal tension pneumothorax Moreover the best treatment of a giant cyst is often by thoracotomy and removal which will allow the rest of a compressed lung to re-expand satisfactorily

The pre-operative investigations must exclude tuberculosis and bronchiectasis the latter disease is a far commoner accompaniment than tuberculosis and it may not be diagnosed unless bronchography is done especially on the left side the lower lobe may be collapsed into a small retro-cardiac shadow and in the emphysematous upper lobe bullous formation may have been the cause of the leak

Thoracoscopy This examination is of value Direct inspection of the lung and pleura may expose the exact cause of the spontaneous pneumothorax and the actual site of the leak. Emphysematous blebs or bullae with or without associated areas of scarring large thin walled cysts possibly congenital in origin or adhesions leading to a pathological area of lung tissue are commoner findings Surprisingly healthy lungs may be viewed and the explanation of leaking from such is difficult Brock has gathered evidence that in this group of patients the porosity of the lung is indicated by the appearance in one or more sites of white bubbles on the surface the appearance well described by him as cuckoo spit In these patients the gentle pressure of a probe on the lung may produce areas of leakage

The thoracoscopic appearances enable the surgeon to decide on the appropriate treatment which may be by surgical exploration or by chemical pleurodesis The safest and according to Brock the most effective treatment the production of chemical pleurodesis may be used for those patients with generalized emphysema porous lungs and apical bullae associated with localized scarrings Large bullous cysts of congenital type or due to over distension in areas of localized emphysema are often best treated by lobectomy local excision or direct suture of the entering bronchus with its associated tear When adhesions leading to a tear in the lung at their base or to areas of small bullous formation are seen their division by the cautery at the time of thoracoscopy may produce rapid, permanent re expansion of the lung at the same time the affected surface of the lung can be painted with 10 per cent silver nitrate

If pleural adhesion is produced in patients with large cysts or bullae the check valve mechanism producing the bullae is left unaffected and progressive distension of these cysts may produce a severe crippling of the respiratory function by the effects of pressure on the remaining lung tissue and by the increase of dead space air since the normal respiratory exchanges do not take place in such distended sacs

Treatment of chronic or recurrent pneumothorax The choice lies between thoracotomy the artificial obliteration of the pleural space or the division of adhesions by thoracoscopy

Brock carried out major surgical resections in 8 patients divided adhesions in 2 and performed chemical pleurodesis in 53 He reserved thoracotomy for patients with cysts or large bullae Brewer (1950) prefers thoracotomy to pleurodesis because it provides a true account of the underlying pathological condition which is usually due to a leak from diseased lung tissue such as congenital cysts emphysematous bullae scar tissue or covered by a thickened visceral pleura which will not allow the rent to seal he also indicates that chemical pleurodesis leads to considerable loss of lung function as estimated by physiological studies Fifteen patients were operated on without death and with great improvement the surgical procedures employed consisted of resections of grossly diseased areas division of adhesions or decortication of a thickened envelope lying on the visceral pleura My own preference is for thoracotomy and I rarely practise chemical pleurodesis

Surgery in pulmonary emphysema: Summary

Surgical measures for the relief of emphysema are limited to the treatment of spontaneous pneumothorax when it complicates the disease, to the removal or obliteration of large air cysts of a lung affected by bullous emphysema that are exaggerating the symptoms,

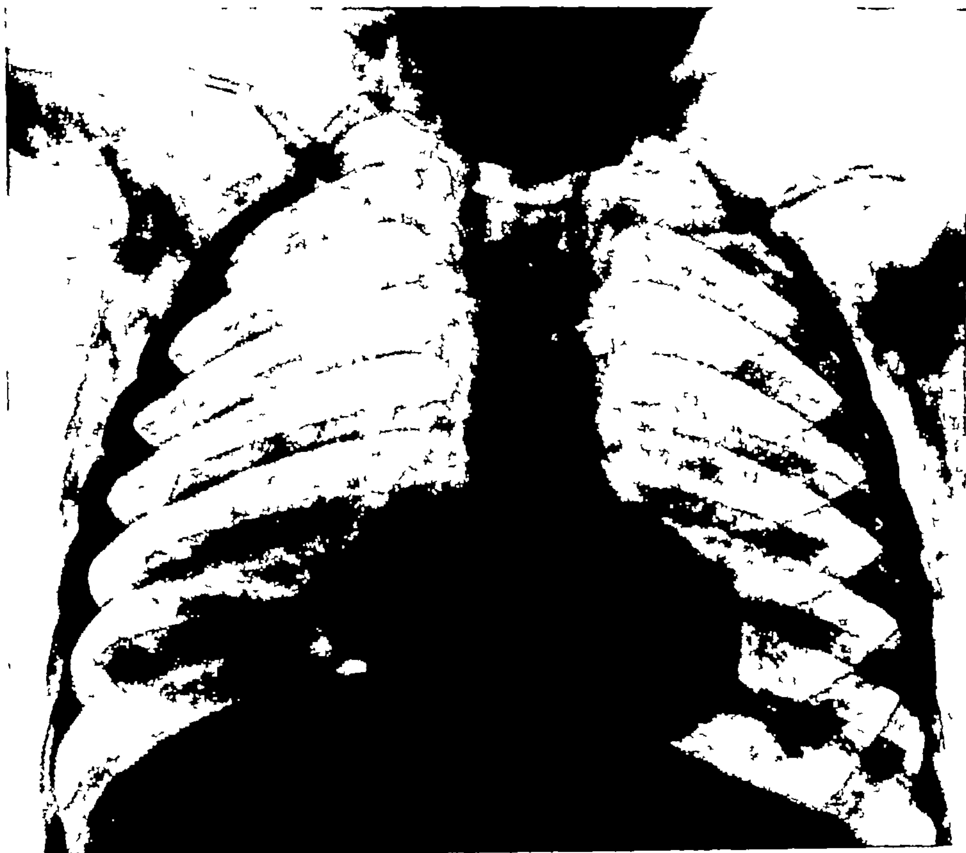


FIG 21 13 —Pneumothorax and surgical emphysema developing as a complication of broncho-pneumonia in a child

and embarrassing the remainder of a diseased but functioning area of lung tissue, and to collapse measures designed either to diminish the capacity of the thorax after pneumonectomy or to remove the piston action of the diaphragm by phrenic nerve interruption in rare examples of bullous emphysema when over-distension is occurring predominantly in the inspiratory phase of respiration

Interstitial emphysema of non-traumatic origin

After crush injuries, gun-shot wounds or thoracotomy, surgical emphysema is common (see pp 89, 541, and Fig 5 1) Quite exceptionally as the result of severe cough, as in broncho-pneumonia or whooping cough, a pneumothorax may develop and if a bronchus or bronchiole of any size has given way interstitial emphysema may follow, the air escaping along the line of the bronchus into the mediastinum and spreading beyond the chest area The condition is serious, suffocative symptoms being associated sometimes with a distending pressure in the mediastinum, which obstructs the flow in the thin-walled veins, so reducing the venous return to the heart Mediastinal emphysema is indeed the only type of surgical emphysema that in itself is serious Relief may be afforded by a small transverse incision above the sternum which opens up the entry to the mediastinum so that the entrapped air can escape The underlying lung infection is treated by antibiotic therapy, oxygen therapy

is used and intrapleural collections of air are removed by the pneumothorax apparatus or by a needle left in the pleural cavity and connected to an under water sealed drainage system.

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CHAPTER 22

PULMONARY HYDATID DISEASE

Though endemic in some areas (Australia, South America, France, Iceland, Yugoslavia) hydatid disease of the lung appears in the practice of thoracic surgery throughout the world In this country many of the patients come from Wales, but some are seen sporadically in all areas The differential diagnosis may be difficult but is important Surgical treatment is safe and curative in most instances

In the human the cystic stage in the life cycle of the echinococcus is seen primarily in the lung in 15 to 20 per cent of the cases, the liver being the commonest harbouring site, not infrequently multiple cysts develop in the liver and one or both lungs at the same time, probably these examples of multiple cysts are not referred commonly to a thoracic surgeon and I have only operated (knowingly !) on two patients out of 40 who had cysts other than in the thorax, one having many cysts in the liver (a Yugoslav), and the other a cyst of the spleen (a Welshman, Fig 25 3) There may be more than one cyst in the lung Bilateral disease of the lungs (Fig 22 3) is not uncommon, the lower lobes are most often involved (Fig 22 1) Widespread dissemination of cysts following rupture into a large blood vessel or the heart (hydatid embolism) has been reported on many occasions but is not common

Natural history of pulmonary hydatid disease. There being no specific remedy for echinococcal disease, natural cure can only result from expectoration through the bronchus or by calcification after the cyst has died In addition to endobronchial rupture the parasitic cyst may burst into the pleura or pericardium, carrying not only the risks of anaphylaxis, but of daughter cyst formation (In one patient for whom lobectomy was done for a complicated, infected ruptured cyst of the right lower lobe of the lung, over a hundred daughter cysts lay in the pleural cavity or mediastinum)* The hope that cure will follow expectoration is not sufficient grounds for advising expectant treatment, for over 20 per cent of the patients die from asphyxia or anaphylaxis during this natural sequel and in many the coughing up of the mother cyst is incomplete and symptoms may recur later The incidence of suppuration in the lung parenchyma after spontaneous evacuation is high, the clinical picture being one of lung abscess, pleural effusion and empyema may follow Intrapleural rupture causes a high death rate from anaphylactic shock and tension pneumothorax (Fig 22 5)

The undoubted fact that complete cure has followed expectoration is no support for a conservative, non-surgical attitude because the death rate from nature's attempt at cure exceeds any surgical hazard Barrett (1947) records only one death after operation for 50 cysts and there has been one death in a personal series of 40 operations

Diagnosis. Frequently symptoms are minimal or absent, an ovoid clear opacity being discovered on routine radiography but many patients come with thoracic pain, haemoptysis and cough Small haemoptyses are undoubtedly the commonest symptoms Dyspnoea is occasionally severe and the cause of the patient seeking relief, the explanation of the dyspnoea is difficult, but may be due to the setting up of the Hering-Breuer reflex, the result of local lung distension affecting the vagal nerve terminations, or possibly is

* This patient seen 8 years later has no evident recurrence

anaphylactic Severe breathlessness may exist when the cyst is quite small A man of 46 years was referred to me because of dyspnoea and the presence radiologically of a small opacity in the right lower lobe a negative search was made for a primary growth on the assumption that this might be a metastasis It was in 1937 and at operation the characteristic surface changes in the visceral pleura consistent with hydatid disease were overlooked a lobectomy was done the diagnosis being made post-operatively The patient recovered well but the feature of chief interest was complete disappearance of dyspnoea the day after the lobectomy Anaphylactic symptoms such as skin urticaria tachycardia and shortness of breath are common

If the cyst has ruptured into the bronchus the one certain diagnostic feature is the discovery of hooklets in the sputum none of the laboratory investigations provide anything approaching a 100 per cent diagnosis The Casoni skin test if active hydatid fluid is available gives a high incidence of positive reaction which is almost unfailingly present in the absence of complications the hydatid complement fixation gives a positive result in from 80–90 per cent of cases An increase in the eosinophils in the blood may or may not be present and this finding is not of great diagnostic value

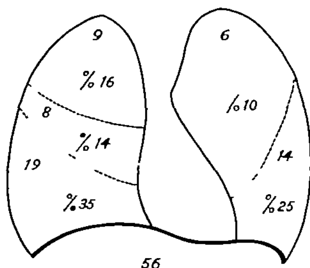


Fig 22 1 —Distribution of cysts in 56 cases. (Professor K L Gurkan, Istanbul)

Radiological appearances An uncomplicated hydatid cyst of the lung gives a slightly ovoid shadow of uniform density it is not truly circular as often stated and although the edges are clear-cut the outline may show indentation where the cyst is pressing against unyielding structures

When complications are present such as pleural effusion surrounding pneumonitis atelectasis or air within the peri-cyst the appearances are notably altered In the unusual event of the affected area of the lung being adherent to the parietal pleura, the outer wall of the cyst appears to be straight If the patient is about to cough up the cyst through a small bronchial fistula the true cyst may become separated from the peri-cyst tissues and a cap of air appears about it (pneumo-cyst) (Fig 22 3)

After expectoration or surgical removal of a cyst a persistent cavity is left in the lung which may become partly filled with pus or fluid, presenting an appearance like that of a lung abscess The tissue around the cyst occasionally shows calcification and this is usually regarded as a sign that the hydatid is dead (Fig 22 4) Inflammatory changes or atelectasis around a cyst may confuse the radiological diagnosis (Fig 22 5)

Since tumours of the lung or mediastinum such as bronchial carcinoma neurofibroma metastatic carcinoma often produce ovoid shadows they should be considered before a suggestion of hydatid disease is entertained.

Surgical treatment Attempts at diagnosis or cure by aspiration are dangerous and foolish The surgical aims are to remove the mother cyst without providing any danger of secondary daughter cysts developing either from contamination of the pleura or as the result of incomplete removal of the laminated lining of the mother cyst and to avoid any danger of hydatid fluid escaping into the pleura or soft tissues of the chest wall Attempts

at aspiration break all these rules and from published experience the method is ineffective and has caused sudden death from pleural anaphylactic shock

The "two-stage" drainage operation is obsolete notoriously even a superficially placed cyst fails to cause dense pleural adhesions and Barrett has emphasized the difficulty of producing pleurodesis by chemical irritants Drainage of a cyst by marsupialization is obsolete because fixation of the lung to the parietal pleura by dense adhesion is uncertain Efforts to supplement the symphysis of parietal to visceral pleura by suture are highly dangerous because after drainage of the cyst a bout of coughing may tear the lung away from the parietes and produce a pneumothorax or more dangerous tension pneumothorax

With modern surgical technique and anaesthesia there is no case to be made against thoracotomy with complete exposure of the lung area containing the cyst or cysts, whether adhesions be present or not The cyst having been fully exposed three courses are open (1) Removal of the cyst completely after partial aspiration of its liquid contents * (2) Removal of the cyst entire without even the help of a preliminary decompressing aspiration (3) Lobectomy or segmental resection (Fig 22 6) Lobectomy is largely reserved for those cases with complications such as rupture with secondary lung infection, segmental resection has a place and perhaps carries a lesser risk than resection-enucleation of leaving bronchiolar fistulae Peschiera (1952) had no mortality in 77 operations (44 lobectomies, 20 segmental resections and 18 resection-enucleations)

Removal of the cyst through a wide thoracotomy incision. As soon as the problem of the open surgically produced pneumothorax had been solved by good anaesthetic technique, surgeons throughout the world began to adopt this method In most of the patients the affected lobe shows a characteristic appearance, the adventitia of the cyst appearing as a white pearly-grey patch under the visceral pleura A hydatid cyst, like a lung abscess, usually presents on the surface of a segment and the so-called para-hilar ones are equally superficial, though the presenting area may be towards the mediastinal pleura, in the lower lobe the cyst may be closest to the diaphragm and this often gives the impression of great depth in site The affected lobe is carefully packed off with saline swabs on which were laid pieces of gauze wrung out in ether which is probably better than 1 per cent formalin

The cyst is partially aspirated, the greatest care being taken to avoid any spilling of the crystal-clear contents which may contain scolices a small amount of ether is then injected and no attempt made to remove the cyst for five minutes The needle having been withdrawn, the hole in the cyst and its adventitia is closed with a fine mosquito forceps While gentle traction is made on this forceps, a cautious incision is made through the adventitia till the germinal layer is exposed a small incision is made through this into the cyst, the remaining contents of which are aspirated by the sucker The flaccid cyst is then lifted out intact, with sponge-holding forceps an inspection of the cyst should show it to be intact except in the area previously entered by the scalpel A cavity in the lung is seen which may ooze a little blood

The obliteration of the cavity An attempt is made to obliterate the cavity of the pseudo-cyst by interrupted catgut mattress sutures After the false surrounding capsule has been peeled away, the incision previously made through the thinned-out overlying lung parenchyma is then closed by sutures The anaesthetist re-inflates the lung and the chest is drained by apical and basal catheters, to which post-operative motor suction drainage is applied for 48 hours

* Leigh Collis has demonstrated clearly that by careful dissection the cyst with its adventitia can be excised intact with complete safety



Fig 22 2

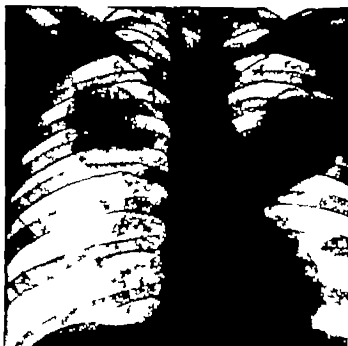


Fig 22 3

Fig 22 2 —Radiograph of hydatid cyst in a Yugoslav soldier aged 25
It was removed by open thoracotomy

Fig 22 3 —Bilateral hydatid cysts.
The one in the left lung shows a small cap of air the classical feature of pneumo-cyst (Mr Ronald Edwards patient.)

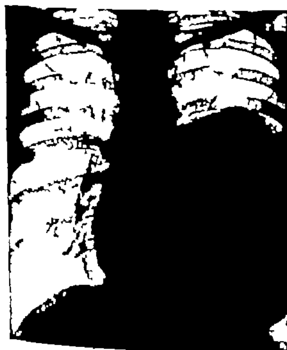


Fig 22-4

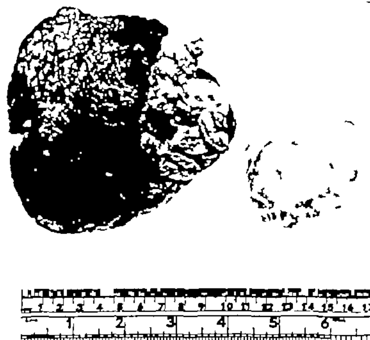


Fig 2* 5

Fig 22 4 —Large hydatid cyst of left lower lobe with peripheral calcification above and below (Mr E G Dolton s patient)

Fig — 5 —A resected right lower lobe and a cyst that had extruded posteriorly into the pleural cavity
The patient, a woman of 33, had sudden pain in the chest followed by collapse at emergency thoracotomy the rupture in the lower lobe was associated with blood stained effusion no evidence of recurrence four years later

Different views on surgical treatment. In my own experience I have removed only 30 cysts by the method described in the preceding paragraphs. I have been able to follow up half of these for 5 years or more and there have been no recurrences. In general, however, surgeons are beginning to feel that whenever possible the cysts should be removed intact. Barrett (1949) described an ingenious method by which the cyst was extruded whole by raising the pressure in the bronchial tree by raising the pressure in the intratracheal tube via the anaesthetic machine after an incision had been made through the adventitious tissue down to the true cyst wall. The lobe involved was held in a bag of thin mackintosh.

Holmes Sellors has described to me the experience of several surgeons with wide experience of this disease in South America. Allemand (1951) believes that in many patients treated by simple extrusion methods the surrounding lung tissue because of bronchiectatic changes frequently causes considerable symptoms later; for this reason he often carries out a segmental resection or a lobectomy. Some South American surgeons after treating the cyst by extrusion methods resect the false cyst wall; this procedure can be awkward and associated with a haemorrhagic operative field. If the false cyst wall is to be excised it seems to me that enucleation resection with removal of the cyst and its surrounding envelope intact would be a better method (Fontana, 1948.)

Lobectomy. The good results that follow the simpler methods for the treatment of peripherally pointing univesicular cysts will not be obtained if they are applied to the cure of cysts complicated by infection and bronchiectasis; in a series of 40 operations for hydatid disease of the lung, I have lost one patient. I was guilty of faulty judgment in attempting to treat an infected cyst of the left lung by thoracotomy and removal of the cyst. The patient had been grossly pyrexial for three weeks after a severe haemoptysis and urticarial reactions of anaphylaxis; a pneumo-cyst was present on the radiograph indicating a bronchial connection and pus was mopped out of the false sac after the membranes had been removed. Lobectomy should undoubtedly have been practised; the patient died 48 hours after operation of a spreading septic condition of the lung in spite of full antibiotic therapy. Deeply sited cysts, multiple cysts, extensive irreversible damage of the occupied lobe, para-hilar cysts and calcification are often indications for lobectomy in addition to the obvious one of associated abscess or bronchiectasis; the low mortality of lobectomy is a further factor in preferring it to other measures in the treatment of cysts which would only be doubtfully cured by simple enucleation.

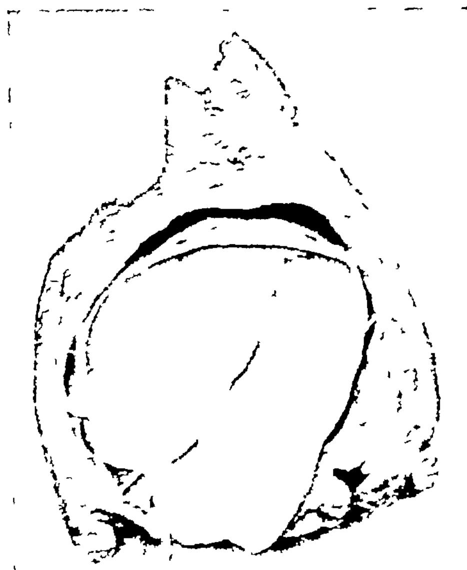


FIG 22 6—Left lower lobectomy specimen

The lower lobe is completely atelectatic. A typical cyst wall surrounded by compressed lung tissue. (Brit J Surg 1937.)

From time to time lobectomy for hydatid cyst will be practised when an exact pre-operative diagnosis has not been made; the general practice of advising exploration of all ovoid and circular "tumours" of the lung of doubtful nature means that a lobectomy is often preferred to direct enucleation of a mass of unknown pathology, and the post-operative examination of such a tumour may indicate for the first time that a cyst is present. I have had this experience on three occasions

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CHAPTER 23

THORACIC INJURIES

The principle underlying the treatment of severe thoracic injuries is to restore rapidly the normal physiology , the measures needed may include all or some of the following procedures the re-adjustment of altered intrapleural mechanics by withdrawing air and blood by aspiration or intercostal drainage , the correction of paradoxical chest wall movements by external pressure or operative fixation , persistent efforts to maintain an adequate supply of air to all parts of the lungs, by encouraging the cough mechanism, the clearing of the major air passages by suction (trans-nasal or bronchoscopic) or by providing a temporary tracheotomy , the administration of oxygen and blood when indicated

Tracheotomy is being increasingly used in the management of severe chest injuries, the reduction of the dead space air and of the resistance to the inspired and expired air, combined with the provision of an opening through which bloody secretions can easily be sucked out is a life-saving measure Tracheotomy should be performed without hesitation and as early as possible in crush injuries of the chest when paradoxical movements, ineffective respirations, dyspnoea, cyanosis and the inability of the patient to cough up bronchial secretions are obvious or are developing

COMPRESSION AND CRUSH INJURIES WITHOUT FRACTURE OF THE RIBS

Severe visceral damage may follow compression injuries of the chest without any obvious loss of continuity of the chest wall Whatever the agent, the sudden contraction or compression of the thorax associated with a shortening of the diaphragm and a tightening of the accessory muscles of respiration, including the abdominal musculature against the closed glottis, may lead to the rupture of alveoli and the tearing of adhesions pneumothorax, haemo-pneumothorax and interstitial emphysema may follow (see Fig 21 13)

An increasing number of tears or avulsions of a main or lobar bronchus or even of the intrathoracic trachea are being diagnosed and treated by direct suture alone or with the help of a fascial or dermal graft (Griffiths, 1949 , Scannell, 1951 , Thompson and Eaton, 1955) They may follow car or aeroplane accidents, after a shearing force associated with sudden increase in intrathoracic pressure The diagnosis is made early or late If early, suspicion of a major tear will follow observations made in a patient with a tension pneumothorax when intrapleural drainage indicates a persistent massive leak of air , this demands thoracotomy and repair by suture with or without graft of the bronchial tear The late, rare example, is represented by the patient who develops atelectasis of a lung or lobe after a crush injury of the chest Bronchoscopy will reveal the state present Treatment may be by reconstruction of the bronchus or by lobectomy or pneumonectomy Even after months or years of atelectasis it is possible in some patients to restore lung function by bronchial reconstruction Such restorations may be effected by direct end to end anastomosis or by the use of the Gebauer dermal graft (Gebauer, 1951). Direct suture wherever possible is better than the use of grafts which are so often followed by fibrosing strictures

Blast lung

The high pressure generated by an exploding bomb or shell may have a tremendous effect upon the casualty even if no open wound is inflicted according to the weight and size of the shell or bomb blast injuries may kill or severely damage someone standing from ten to three hundred feet away from the explosion. The blast effect is produced by the positive pressure exerted as a blow on the body if this force strikes the chest when the glottis is closed the sudden rise of intrapulmonary pressure may rupture large vessels but more usually tears alveoli At the same time the ribs are driven inwards and indent the lung parenchyma with consequent bruising In subjects who are not killed outright the severe lung damage is followed by a traumatic oedema which grossly interferes with the normal exchanges of gases and anoxia rapidly develops Complications such as pneumothorax or atelectasis (the result of bronchial obstruction) were noted in the last war In the early stages of treatment absolute rest with the administration of oxygen is essential Ineffective cough should be assisted by trans nasal suction after local anaesthetization of the pharynx and larynx associated tension pneumothorax calls for immediate decompression (see Fig 23 4) Tracheotomy may be essential

Mediastinal emphysema (interstitial emphysema)

Surgical emphysema is common after thoracic wounds and intrathoracic operations air escaping through a pleural tear into the muscular and fascial planes reaching in extreme cases up to the face and down to the genitalia the crepitations so easily felt by the patient and by palpation are a commonplace of thoracic surgery and though capable of causing extreme discomfort are rarely dangerous and rapidly re-absorb their treatment is primarily that of the thoracic lesion that has allowed the escape of gases into the tissues

Mediastinal or interstitial emphysema may follow a rupture of alveoli a bronchus or the oesophagus air escapes along the planes of the loose tissue that invest the bronchi and mediastinal structures to distend the mediastinal spaces from here it spreads into the retroperitoneal tissue and up into the neck where it appears as a crepitant swelling in the suprasternal notch

Mediastinal emphysema may present as a rare complication in new born infants after a difficult delivery in children with severe whooping cough and after antero-posterior crush injuries of the chest it is a possible complication of the rare spontaneous rupture of the oesophagus The escape of the air along the routes indicated provides a natural decompression and if the pre-disposing cause in itself is not fatal subsidence is the rule rarely however the pressure in the mediastinum may be so great that the large veins in the space are compressed and the venous return to the heart is grossly interfered with and asphyxia results In the presence of such a small incision under local anaesthesia should be made in the suprasternal notch with wide division of the loose areolar tissue and the wound left open under a simple gauze dressing protection to allow air to escape Few thoracic surgeons have ever had to perform this operation the treatment of mediastinal emphysema as of surgical emphysema, involves also the correction if possible of the intrathoracic cause of the escape of air

Cardiac contusion

Perhaps the only cause of note is violent compression of the thoracic cage as in car injuries in which the steering wheel is driven against the sternum but even this severe injury is unlikely to cause damage confined to the heart Sudden death in such happenings may well be due to severe anoxia the result of concomitant lung injuries Following cardiac contusions however signs of myocardial insufficiency may follow with characteristic electro-cardiographic changes this will be more likely in patients with arterio-sclerosis or

pre-existent myocardial damage Suspected or proved cases of cardiac trauma should be treated as if there had been an attack of coronary thrombosis

Cardiac injuries are discussed further in Chapter 13



FIG 23 1—Severe multiple injuries, abdominal, fracture of left humerus and cerebral laceration

A severe crush injury of the left chest had produced paradoxical movements of that side and there was also a tension pneumothorax Tracheotomy, traction on the floating chest segment by means of wire encircling the ribs and two intercostal tubes have relieved grave thoracic complications *The tracheotomy tube can be used for intermittent bronchial suction and the administration of oxygen, or assisted respiration*

COMPRESSION AND CRUSH INJURIES WITH FRACTURE OF THE RIBS AND STERNUM

Apart from the wounds of warfare these are usually associated with an intact overlying skin and rarely break inwards to produce laceration of the lungs, haemoptysis or pneumothorax are more often due to the effects of lung contusion or a sudden rise in intrapulmonary pressure as the result of the compression force, haemothorax is a commoner complication than either of the above-mentioned complications Its presence may not be obvious until a few days after the injury and if undetected and untreated permanent crippling of lung and chest wall function may result

Fracture of the ribs

Most fractures are the result of anteroposterior compression injuries when this is so, the ribs fracture most readily in the line of the axilla, the rib breaking outwards, but frequently the rib may give way more posteriorly just in front of the angle of the ribs Several ribs may be fractured in two places to leave a segment of the chest wall loose or floating with the consequence that the breathing will become paradoxical

The pain from a fracture of a single rib is certainly no greater than produced daily in the operation of thoracotomy. Tight strapping in itself is a cause of considerable discomfort If pain is severe the best treatment is bed rest for a few days and the intercostal injection of procaine Moderate paradoxical breathing must be checked by firm strapping over pads of wool or by a well moulded plaster of Paris slab defective coughing may be followed by atelectasis calling sometimes for treatment or bronchoscopic suction Moderate doses of pethidine or morphine will relieve pain, oxygen is used if cyanosis is present In gross injuries tracheotomy may be life-saving (p 540)

The conservative treatment of the unstable chest wall has recently become the subject

of criticism which has been well presented by Crutcher and Nolen (1956) Operative fixation of the floating ribs by open operation rapidly prevents the paradoxical movement reduces the period spent in hospital and leads to rapid return of function The fixation may be by silk or wire sutures passed through holes drilled on each side of the fractures or by the use of intramedullary nails Alternatively by direct traction methods sutures or metal clips are passed round the floating ribs and held out by weights applied over pulleys Strong steel wire covered by polythene tubing can be passed round several ribs under local anaesthesia to these are attached weights of 2–5 lb suspended over pulleys In injuries severe enough to require such measures a temporary tracheotomy will almost invariably be required (Fig 23 1)

Fracture of the sternum

The usual fracture is transverse near the junction of the body with the manubrium and usually the chest wall remains stable Bed rest will relieve the pain but occasionally in elderly subjects the lower lobes of the lung may collapse because the patient cannot expectorate bronchial secretions Intratracheal suction or bronchoscopy may be required and the pain should be relieved by the local injection of procaine in oily suspension into the site of fracture

If the sternum is completely fractured and the chest wall is unstable with obvious effects on the breathing mechanism the two segments should be elevated into position and fixed by stainless-steel sutures

PENETRATING AND PERFORATING WOUNDS

A penetrating wound of the chest implies a solitary entrance wound with lodgment of the missile deep to the plane of the ribs a perforating wound is usually associated with a wound of entry and exit except in the case of stab or bayonet wounds If the pleural or pericardial cavities or the mediastinum have not been involved the problems are those of a wound anywhere in the body The significance of these wounds depends entirely on the structures injured and the development of a haemothorax or haemo-pericardium If the lung is wounded in an area free of large vessels the bleeding is usually rapidly self arrested because of the low pulmonary arterial pressure and the salutary effects of lung collapse a haemothorax that develops in a patient who survives the initial trauma is usually due to bleeding from a vessel in the systemic circulation such as an intercostal artery Ten per cent of battlefield casualties who survive to reach a medical centre have thoracic wounds and the chief complication seen is haemo pneumothorax the treatment of this represents the chief surgical duty after immediate physiological derangements have been corrected.

Some physiological considerations Thoracic injuries severe enough to threaten life cause the same physiological disorders whether in civilian or military practice the lessons of warfare tend to be forgotten in peace-time but no implied differences should allow us to minimize the force of Churchill s (1944) statement that two main aims control the whole of our treatment the first object is to save life by the immediate correction of disordered physiological states and the second is to obtain rapid return of function and to prevent or correct sepsis

The disordered physiology Anoxia is the cause of death in chest injuries or wounds and may be due to haemorrhage or severe mechanical effects in cardio respiratory physiology

which interfere with adequate lung ventilation and venous return Even with an intact pleural cavity the ventilation and gaseous exchange of the lungs may be grossly interfered with, as in multiple rib fractures when a large segment of the chest wall is mobile and unstable Such a " floating " area may produce effects as severe as an open pneumothorax because of paradoxical breathing with inspiration the loose segment is sucked into the thoracic cavity while the opposite side expands and during expiration it is pushed out, a minor degree of this paradoxical movement is seen after extensive thoracoplastic rib resections Its chief pathological effect is to allow some to-and-fro movement of gases from one lung to the other, and it is obvious that carbon dioxide will not be eliminated adequately



Fig 23 2



Fig 23 3

Fig 23 2 —Penetrating wound of right chest with small retained foreign body in upper lobe
Traumatic pneumothorax and atelectasis of right middle and lower lobe Adhesions are holding up the upper lobe

Fig 23 3 —Areas of atelectasis due to blood in the bronchial tree after a perforating gun shot wound of the left chest
The right middle and lower lobe of the wounded side have collapsed as the result of inhalation of blood from the left side

The carbon dioxide tension in the blood will rise and the central stimulation of the respiratory centre accentuates the depth of breathing and so aggravates the paradoxical breathing, the decrease in oxygen tension in the alveolar air will quickly lead to cyanosis with all its ill effects The efficiency of the cardio-respiratory function is also hampered by the development of exaggerated displacement of the mediastinum from side to side with each inspiration and expiration The interruption of this paradoxical movement by applying firm pressure over the floating area of the chest wall, or by more deliberate surgical methods, often combined with tracheotomy until stability has been achieved (8–14 days) is essential as described earlier

The open, sucking pneumothorax Although a simple pneumothorax greatly diminishes the function of the lung on that side it does not interfere with the gaseous exchange of the other lung and dyspnoea is not the rule, the open pneumothorax is quite different Because air can be sucked in and expelled from the wound the loss of the sub-atmospheric pressure in the pleura leads to collapse of the lung on that side and to its gradual loss of ventilatory function The serious effect of the open pneumothorax depends upon the exchange of air from one side to the other across the tracheal bifurcation, air from the sound lung can

pass just as readily into the bronchus of the collapsed lung on the injured side as it can through the glottis since both the upper air passages and the chest wall opening are under the same degree of atmospheric pressure and paradoxical breathing results with the exchange of air steadily rising in carbon dioxide content from the sound to the collapsed lung Under this burden the respiratory exchange of the good lung deteriorates in the presence of a rising tide of carbon dioxide and a deficiency in oxygen. As dyspnoea increases the pendulum movement of the mediastinum moves more violently from side to side obstructing the venous return to the heart and so leading to a fall in cardiac output The conversion of the open pneumothorax by closure of the wound by suture or by an efficient pad at once converts it into a simple pneumothorax and abolishes the pendulum movement of air from one lung to the other with an immediate improvement in the physiological state

Other factors Respiratory exchange will be further embarrassed if the tracheo-bronchial passages become obstructed by mucous secretion or blood especially if pain is so severe that the cough mechanism becomes ineffective Collapse of the whole lung or of a lobe may follow (Fig 23 2) bleeding into the bronchus may produce areas of collapse in both lungs (Fig 23 3)

Tension pneumothorax A positive pressure may develop in the pleural cavity as the result of the accumulation of air through a leak in the lung of a valvular type or as the result of the accumulation of a large haemo pneumothorax The rising tension will displace the mediastinum to the opposite side impairing the ventilation of that lung and hindering a satisfactory venous return to the heart Anoxia cyanosis and an obvious engorgement of the neck veins will develop and a pulse of low pressure will indicate the decreased cardiac output it is not a common combination though frequently diagnosed Its relief is usually prompt after paracentesis of the pleural cavity when air or fluid are withdrawn If a tension pneumothorax recurs promptly after air aspiration it is evidence of a persistent lung leak and the continuous withdrawal of air by an indwelling thoracic needle attached to rubber tubing leading to a water-sealed drainage will be required *

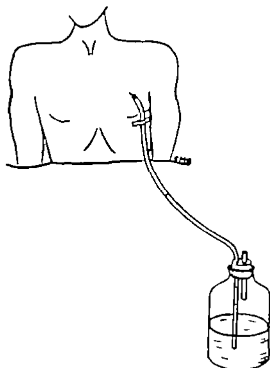


FIG 23 4 —Method used for urgent treatment of a tension pneumothorax by means of an indwelling needle connected to a water-sealed drain

Treatment of thoracic injuries or wounds

Whether the injury be a simple fracture of a single rib or a serious wound involving not only the thorax but the abdomen a routine should be followed serious sequelae may follow a simple rib fracture because an overlooked haemothorax has been allowed to organize with severe crippling of lung and chest wall function. In more severe injuries the correction of physiological disorders may be achieved successfully only to be followed by grave and often permanent complications such as pleural or pulmonary infection because too little attention has been paid to the full restoration of lung and chest wall function.

* The possibility of a major tear of a bronchus and its treatment has been considered on page 540

It seems clear that the hard-won lessons of war should be applied to civilian che trauma, though the timing of the interventions may be different because the need fo evacuation of a chest casualty is not required as in war-time indeed the two phases ma be merged into one with great advantage provided the full requirements of each are fulfille Before treatment is instituted a full clinical assessment is essential

The clinical assessment Whether the injury be caused by a missile or follows a crushin or motor-car accident the first duty is to ascertain, as soon as possible, if the injury is purel thoracic or associated with lesions elsewhere such as the spine or abdomen The thorac abdominal wound is an obvious example, and in crush injuries serious chest damage ma be complicated by renal, splenic, hepatic or other visceral ruptures rigidity of the abdome is a common accompaniment of purely thoracic injuries and indeed was seen in most the haemothoraces caused by gun-shot wounds of the chest during the first 24 hours careful study of the external evidence provides information, but difficulty is experience in warfare in assessing the probable course of a missile when the wound is of the lodgin type there being signs only of one external wound

Wounds or injuries elsewhere having been detected or excluded, the clinical examina tion of the chest and cardio-respiratory follows the usual lines dyspnoea and haemoptys may be obvious indications of severe intrathoracic mischief an open sucking pneum thorax will be detected at once and immediately closed by the application of a firm sealin pad fixed as a first-aid measure by strapping The position of the apex beat of the hea and the trachea may provide evidence of mediastinal displacement due to the presenc of air or blood or both in the pleural cavity paradoxical breathing in patients with th "stove-in" chest indicates the need for immediate fixation of that side by pads an firm strapping Surgical emphysema which may rapidly spread beyond the confines o the chest wall is declared by the characteristic subcutaneous crepitations that crack under the examining hand applying light pressure

Percussion and auscultation may reveal the presence of a pneumothorax or of collapsed lung or lobe of a lung, but both may exist without obvious auscultatory evidenc and the stethoscope is not a reliable method of detecting serious intrathoracic lesions an can never rival the accuracy of radiological findings, a comparatively large haemothora may exist with surprisingly few physical signs It is important to remember that muc pleural fluid may be present without clinical evidence of mediastinal displacement C greater value is the detection of dullness to percussion associated with absent breath sound but complete reliance on this valuable method of examination is not wise

Unless the patient requires urgent correction of dyspnoea, the result of a sucking ope wound or of a tension pneumothorax, an immediate radiological examination is essentia and should precede all operations or the aspiration of haemothorax fluid if the patien is unfit to be examined by radiography he is certainly too ill to be subjected to majo surgery apart from the closure of a sucking open pneumothorax or the relief of an obviou tension pneumothorax The availability of X-ray apparatus in the Casualty Clearin Station in the last war was often of inestimable value and saved many lives the sam can be said of the value of the portable X-ray machines in the wards of a civilia hospital

The first phase of treatment

The same principle, the immediate correction of disordered physiological states, applie to the different classes of injuries These are penetrating and perforating wounds, non penetrating wounds, abdomino-thoracic wounds, and compression wounds of the lung o

heart in this group belong the important class of blast injuries The chief causes of severe symptoms or of death are anoxia and blood loss the anoxia may result from the mechanical effects of paradoxical respiration from tension pneumothorax or collapse of wide areas of lung the result of bronchial obstruction from intrabronchial mucous plugs or haemorrhage

Severe haemorrhage from damage to large vessels or the heart will produce anaemic anoxia. In the correction and relief of these states the closure of sucking open thoracic wounds the arrest of haemorrhage the relief of paradoxical breathing and the decom pression of a large haemo-pneumothorax or a tension pneumothorax require immediate application The clearance of blocked air passages by trans nasal suction or bronchoscopic aspiration play an essential mechanical role while the relief of pain the replacement of severe blood loss by transfusion and the administration of oxygen by an efficient method will be at times of vital complementary assistance in restoring normal lung ventilation and an efficient cardio vascular system These measures form the chief agents employed for the relief of the labouring cardio respiratory system and are of greater importance than major surgical interventions at this stage Tracheotomy may be indicated

(a) **Correction of open pneumothorax and of paradoxical breathing The treatment of shock** Whatever the cause an open sucking pneumothorax wound will produce increasing dyspnoea and cardio vascular distress unless closed closure is effected immediately by the use of air tight pads firmly fixed in place Suture without excision of the wound edges, devitalized muscle and loose rib fragments is dangerous as such closure is attended by a high rate of infection in the thoracic wall layers and in the pleura. Many penetrating and perforating wounds produced by high velocity missiles such as rifle bullets or stabbing do not in fact suck and may not require excision The real sucking wound should only be sutured after adequate wound excision

In the wounds of warfare the greatest judgment and experience is required before a formal thoracotomy is performed during the first phase of treatment if a large sucking wound is excised it may be tempting to carry the exploration sufficiently widely to explore the whole pleural cavity this is not always advisable and the surgical endeavour should be to provide a safe closure after a rapid examination has allowed easily accessible foreign bodies in-driven fragments of rib and blood clots to be removed Lung tears however formidable they appear at this operation should not be excised and the advice that wedge-shaped resections or even lobectomies should be carried out will not commend itself to the surgeon with extensive war time experience of these conditions seen soon after wounding I know of only one lobectomy being practised for gun-shot wounds of the chest in the whole of the 1939–45 war

Lung lacerations rarely bleed severely such bleeding points are underpinned with fine catgut sutures Since gas gangrene does not occur in the lung there is no need for the excision so necessary in the case of wounds elsewhere

The chief exceptions to this attitude of cautious intervention are thoraco abdominal wounds bleeding from large vessels such as the subclavian vein and cardiac wounds that have survived the original trauma

In closing the sucking wound the pleural membrane is not amenable to direct suture and the defect is sealed by suture of the overlying muscles If the patient is to be retained in the same hospital the skin can be closed but if he is to be evacuated in the course of military operations the skin is left widely open the wound being lightly packed with dry gauze Delayed primary suture can be effected safely at the centre to which he will be evacuated

Bleeding in thoracic wounds Apart from wounds of the great vessels and heart which are often immediately fatal, most intrapleural haemorrhage comes from the chest wall injury and only in small part from the lung The low vascular pressure in the latter is usually controlled by its associated collapse towards the mediastinum, unless it is held out by adhesions, the result of previous lung inflammations In wound excisions the intercostal vessels are frequently seen to be torn and bleeding and require ligation

The treatment of shock The chief essentials are the relief of pain, the correction of blood loss by carefully controlled blood transfusion (excessive transfusion is dangerous), the correction of anoxia by taking measures to keep the airways clear and providing oxygen the haematocrit findings are of considerable help in estimating the volume of the blood transfusion

The correction of paradoxical breathing The conversion of the open sucking pneumothorax to a closed one corrects this In wide disruptive injuries of the thoracic cage the prevention of paradoxical movements and the associated to-and-fro passage of air from one bronchus to the other is achieved by firm padding of the loose chest wall segments The object may be achieved better by operative fixation (p 543), the injection of an oily solution of procaine into the posterior intercostal spaces and the administration of oxygen (preferably in a tent, though an oxygen mask will have to be used in warfare) will usually relieve the dyspnoea

(*b*) **Haemothorax and haemo-pneumothorax.** The adequate, early treatment of haemothorax is the most important single duty in the treatment of chest trauma, for this is the major complication of chest injuries, military or civil In 1,000 consecutive chest wounds treated in Italy in the hospital in which I worked, 839 were complicated by a haemothorax no doubt this incidence is an unusually high one because only patients with severe or suspectedly severe wounds of the chest were referred there

The dangers of a haemothorax or a haemo-pneumothorax are undesirable mechanical effects upon the lung, chest wall and the mediastinum and the risks of their subsequent infection These can be avoided largely by early aspiration of the intrapleural fluid, for this corrects abnormal pressure effects, encourages rapid lung expansion, normal chest wall and diaphragmatic function, and removes an admirable habitat for the growth of organisms The fear, still occasionally expressed, in spite of the much-publicized experience of warfare, that early aspiration may restart haemorrhage is unfounded and contrary to hard clinical experience In the last war, the practice of aspirating a haemothorax twelve hours after wounding was widely accepted Since the bleeding is usually from the chest wall there is no danger of restarting pulmonary haemorrhage, for clotting in the pulmonary parenchyma is rapid and effective The whole aim of treatment being to obtain full and rapid lung re-expansion, the use of air replacement to maintain collapse of the lung, with the object of preventing lung bleeding, has no logical support and should not be practised

Some clinical and biological features of haemothorax. In the course of days a small haemothorax may become a large effusion, quite apart from any continued bleeding into the pleura The blood itself acts as a pleural irritant, exciting the transudation of serous fluid, and even if aspiration is done twelve hours after the wound or injury the removed fluid usually has a red cell count and haemoglobin percentage below 50 per cent of the figures of normal circulating blood Blood in the pleural cavity clots at two important stages any surgeon who has dealt with the primary phase of the treatment of gun-shot wounds of the thorax knows that bulky red jelly-like clots are commonly present; the more extensive the damage to the chest wall and the lung, the greater is the tendency to clot formation, due no doubt to the release of clotting enzymes Under the influence of

chest wall and cardiac movements defibrination can and does take place the solid elements of the haemothorax fluid becoming adherent to the parietal visceral and diaphragmatic pleura infection with certain organisms usually of mild virulence may accelerate the process of intrapleural thrombosis Once the clotting process has become extensive large masses of fibrinous deposits appear and often form multiple pockets which enclose air and sero-sanguineous fluid

The clotted haemothorax is in reality a compound process in which serum blood cells and fibrin are entangled If left in place this coagulation becomes organized on to the chest wall and visceral pleura with great impediment to the movements of lung and the parietes. A cortex of sero-fibrinous material readily forms and if exposed by open operation from the second to sixth week can be readily peeled off the structures it encases Such an operation was employed with great frequency in the war time clotted haemothorax but exactly the same intervention is required for the occasional casualty in civil practice If left undisturbed the peel' becomes densely organized and invaded by firm blood vessels but even at a late date an area of separation can be found at operation as in the decortication operation for chronic empyema tuberculous or pyogenic

In addition to the severely deleterious effects on lung and chest wall movements the clotted haemothorax readily becomes infected and the advent of sepsis alters the clinical picture

The mechanical effects may be expressed by dyspnoea and cyanosis the displacement of the apex beat and trachea together with the typical percussion and auscultation features of a pleural effusion when present make the diagnosis obvious but these features are not always of the classical pattern and radiology is essential to disclose the estimated size of the haemothorax the effusion occasionally may be extrapleural (d Abreu Hodson and Litchfield, 1944) Evidence of complicating infection is not as easily obtained as might be imagined the infected haemothorax is naturally associated with a daily pyrexia of 99-100° and this will be exaggerated if there is an associated collapse of a lobe of the lung in which organisms multiply rapidly The bacteriological examination of aspirated fluid is not always decisive as the exploring needle may overlook pockets of infected haemothorax fluid when a multilocular clotted effusion is present Infection however is proved when there is significant pyrexia on the microscopic and macroscopic appearances of aspirated fluid and when pathogenic organisms are revealed by direct bacteriological examination or by culture (d Abreu Litchfield and Thomson 1944) When the aspirated material from a haemothorax changes daily from clear red to turbid pink or salmon-coloured fluid infection is present

Treatment of the simple uninfected haemothorax Thorough early aspiration and the use of breathing exercises under a trained physiotherapist are the essentials the techniques employed depend largely on radiological appearances and unless postero-anterior and lateral films are available attempts to withdraw fluid may fail or be inadequate At the first aspiration local anaesthesia is preceded by a pre-operative sedative such as omnopon and hyoscine and the patient is propped up in as comfortable a position as possible to enable the operator to insert the needle at the most appropriate site after a study of the X rays as in all effusions the diaphragm on the affected side is raised and the selection of too low a site for the paracentesis is a common error and a frequent cause of failure to contact the fluid. Much of the air and haemothorax fluid is withdrawn as the aim is to secure early lung re-expansion air replacement is never practised as a routine though the occasional introduction of a little may be required if the patient becomes dyspnoeic at the close of the performance A little air may be let in to enable post aspiration radiographs to

demonstrate loculations that may be present At the end of the aspiration 1 mega unit of penicillin are left intrapleurally if subsequent bacteriological examination shows that there are no penicillin-sensitive organisms present, this may be omitted after three withdrawals or replaced by a more suitable antibiotic if the organisms are resistant The paracentesis should be repeated on alternate days until only a little serous fluid remains and the radiograph shows a satisfactory pleural state with lung re-expansion

Thoraco-abdominal wounds The reliance placed on a judicially conservative management of most thoracic wounds in which physiological derangements can be corrected by relatively minor surgical measures cannot be justified in the more serious thoraco-abdominal wounds If an abdominal viscus (apart from the liver) has been injured, its prompt care by aggressive surgery is essential and governed by the principles that guide the management of abdominal wounds Intra-abdominal bleeding and peritonitis are far more lethal complications than those associated with haemothorax or pleural infection The mortality rate of thoraco-abdominal wounds varies between 20 to 50 per cent (Betts, 1946, Blackburn and d'Abreu, 1945) It is important to remember that if the wound of entry is in the thorax (thoraco-abdominal) the prognosis is better than if the wound is in the reverse direction (abdomino-thoracic), because in the latter, hollow viscera are more frequently damaged and this plays an important rôle in governing the mortality rate

Pre-operative estimation of the patient A full physical examination of the chest and abdomen may confirm the estimated path of the missile, this latter point is easily judged if there is an entry and exit wound but obvious difficulty presents in the instance of a penetrating, lodging wound The physical signs of a peritoneal wound include abdominal pain, rigidity, tenderness, absence of peristaltic sounds and occasionally absent liver dullness, considerable difficulty is experienced if the upper abdomen on the side of the wound is the only site of rigidity, as this may be caused entirely by the thoracic wound

If reasonable doubt is entertained as to the presence or absence of an abdominal visceral wound, exploration is advisable and should be carried out as soon as the cardio-respiratory derangements have been corrected by first-aid measures already described

The choice of incision for the abdominal exploration If an adequate operation can be performed through one incision, such an approach carries enormous advantages over two separate ones, there can be no doubt that the mortality rate in the last war when the abdomen and thorax were explored through two separate incisions was extremely high A purely abdominal approach is justified if the chest lesion is insignificant and the problem of pre-operative assessment is essentially an abdominal one requiring no operation on the chest It should be stated at once that the combined thoraco-laparotomy approach with division of the diaphragm gives poor access to the lower abdomen In the typical thoraco abdominal wound the abdominal viscera damaged are usually the spleen, liver, stomach, kidney and the colon, especially in the splenic flexure area All of these wounds can be adequately dealt with by thoraco-laparotomy

The outstanding advantages of the thoracic approach are

(1) repair of the diaphragmatic wound is simple and free from the severe difficulties of closure through an abdominal approach, if the diaphragm is not closed the post-operative incidence of chest complications is raised and later complications from a diaphragmatic hernia are not uncommon,

(2) the repair of lesions of the upper half of the stomach and exteriorization of a damaged splenic flexure of the colon are easier through this route than by laparotomy alone,

(3) splenectomy through a trans-diaphragmatic approach is a simple procedure

(4) with good anaesthesia the patient can be maintained in a lighter plane of anaesthesia as relaxation is more easily obtained

(5) the pleural cavity can be cleared completely of clot missiles or fragments of clothing thus greatly diminishing the post-operative risk of pleural and pulmonary complications In patients treated entirely by an abdominal incision the incidence of thoracic complications was higher than in those subjected to a combined thoraco laparotomy approach this was especially so when intestinal or gastric contents had soiled the pleural cavity

Finally the thoracic approach enables a correct excision of the chest wall wound to be done and thus greatly decreases the empyema incidence

As the late war progressed increasing confidence was placed in thoraco-laparotomy the advances in the use of this incision for such operations as oesophagectomy total gastrectomy and splenectomy since the war have only heightened the indications for this approach in this type of wound but failures will follow if the full post-operative regime fails to take care of such post-operative complications as haemothorax and atelectasis in addition to the accepted rules of management of the abdominal state by measures such as intragastric suction and adequate fluid and electrolyte replacement

The second phase of treatment

Once the dangers to life from disordered thoracic physiology have been corrected by the measures discussed attention must be paid constantly to the prevention and treatment of sepsis and the rehabilitation of lung function Basically both these aims are largely achieved when the lung is fully expanded and in contact with a well healed intact chest wall The chief hindrance to this happy result is the development of an empyema the clotting and organization of a haemothorax and the collapse of the lung or one or more lobes Fortunately by correct handling of the haemothorax the use of antibiotic therapy and of physiotherapeutic measures combined when needed with bronchoscopic or trans nasal suction of intrabronchial plugs of muco-pus these complications are readily avoided In some patients however a haemothorax will clot become infected and shut off into pockets that resist all attempts at aspiration.* From experience in the last war in all theatres it is clear that such complicated haemothoraces should be treated by major thoracotomy removal of the products of the haemothorax and decortication of the organized exudate and blood clot on the pleural surfaces The same approach should be employed in the problem of post traumatic empyema the aim being to obtain immediate and complete re-expansion of the lung with the avoidance of persistent and discouraging tube of the empyema

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(3) splenectomy through a trans-diaphragmatic approach is a simple procedure

(4) with good anaesthesia the patient can be maintained in a lighter plane of anaesthesia as relaxation is more easily obtained

(5) the pleural cavity can be cleared completely of clot missiles or fragments of clothing thus greatly diminishing the post-operative risk of pleural and pulmonary complications In patients treated entirely by an abdominal incision the incidence of thoracic complications was higher than in those subjected to a combined thoraco laparotomy approach this was especially so when intestinal or gastric contents had soiled the pleural cavity

Finally the thoracic approach enables a correct excision of the chest wall wound to be done and this greatly decreases the empyema incidence

As the late war progressed increasing confidence was placed in thoraco laparotomy the advances in the use of this incision for such operations as oesophagectomy total gastrectomy and splenectomy since the war have only heightened the indications for this approach in this type of wound but failures will follow if the full post-operative regime fails to take care of such post-operative complications as haemothorax and atelectasis in addition to the accepted rules of management of the abdominal state by measures such as intragastric suction and adequate fluid and electrolyte replacement

The second phase of treatment

Once the dangers to life from disordered thoracic physiology have been corrected by the measures discussed attention must be paid constantly to the prevention and treatment of sepsis and the rehabilitation of lung function Basically both these aims are largely achieved when the lung is fully expanded and in contact with a well healed intact chest wall The chief hindrance to this happy result is the development of an empyema the clotting and organization of a haemothorax and the collapse of the lung or one or more lobes Fortunately by correct handling of the haemothorax the use of antibiotic therapy and of physiotherapeutic measures combined when needed with bronchoscopic or trans nasal suction of intrabronchial plugs of muco-pus these complications are readily avoided In some patients however a haemothorax will clot become infected and shut off into pockets that resist all attempts at aspiration * From experience in the last war in all theatres it is clear that such complicated haemothoraces should be treated by major thoracotomy removal of the products of the haemothorax and decortication of the organized exudate and blood clot on the pleural surfaces The same approach should be employed in the problem of post-traumatic empyema the aim being to obtain immediate and complete re-expansion of the lung with the avoidance of persistent and discouraging tube drainage of the empyema.

Treatment of the clotted and infected haemothorax

If the criteria of infection already mentioned develop or a pleural haematoma is present determined aspiration with appropriate intrapleural and parenteral antibiotic therapy may cure some but major surgical interventions will be indicated when the haemothorax is clotted loculated or infected and when the amount of intrapleural fluid does not decrease rapidly after aspiration therapy If aspiration methods are employed for too long the lung fails to re-expand as it lies imprisoned beneath its sero fibrinous envelope and the chest wall

* Samson and Burford (1947) who did so much in the last war to establish the operation of decortication found that 10 per cent of patients with battle incurred haemothorax showed evidence of extensive clotting and that such a complication led to infection far more frequently than in unclotted effusions

movements steadily decrease The dangers of a chronic empyema and of a "frozen" lung and chest wall can only be overcome safely by thoracotomy, clot removal and decortication of the lung and parietal pleura including the diaphragmatic surface The safety of this method and its excellent results were established beyond doubt in the last war the chronic disabling empyema so often seen in the Ministry of Pensions Hospital for years after the 1914–18 war is today quite exceptional

The operation The principles are the same whether obvious infection is present or not and the application of this war-time operation to the cure of empyema of non-traumatic origin has been discussed in Chapter 6

A wide thoracotomy is necessary and the sixth or seventh rib may be excised or an intercostal incision with division of one or more rib back ends is excellent the lung must be freed sufficiently in any adherent areas before the rib spreaders are placed and opened All fluid and fibrin and blood clots are thoroughly removed from the pleural space and this entails the deliberate breaking down of any loculated pockets, infected or uninfected The lung will be seen encased in its coat of imprisoning exudate beneath which will be a normal shiny bluish pleural membrane The immobility of the lung and the obliteration of the normal fissures will be obvious The enclosing membrane is carefully incised down to the normal pleura in cases older than four to six weeks the fibro-elastic membrane so well described by Samson and Burford will be laminated and some difficulty may be experienced in seeking out the true layer of dissection, which lies immediately over the pleural membrane to which it is connected by tiny blood vessels if organization has proceeded to that stage

Once the membrane has been incised sufficiently, in several directions if need be, it can be grasped in forceps and peeled off the lung by a mixture of finger, swab and scissor or knife dissection. If the lung is penetrated slightly air will bubble out, this is not serious and usually stops after the application of a moist swab, though occasionally very fine sutures may be required for the larger tears in the area of any lung wound the fibrotic membrane should be left intact after a circular incision has been made around it The whole lung must be mobilized thoroughly and the fissures completely defined It is an advantage to remove the peel as thoroughly as possible off the diaphragm and parietal pleura

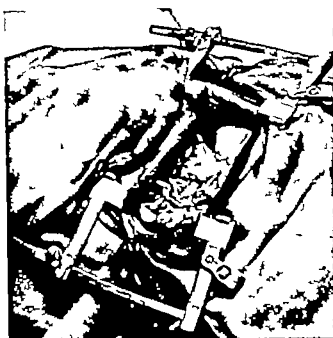
Throughout the operation the anaesthetist should gently distend the lung, as this facilitates the decortication and enables an estimate to be made of the thoroughness of the release obtained

At the end of the operation the chest is closed, drainage being provided by one or more intercostal catheters to which gentle motor suction is applied (Price Thomas and Cleland, 1945) In most instances the lung is fully re-expanded in 3–4 days and the tubes are removed any subsequent effusions are treated by aspiration Active breathing exercises are commenced immediately

If any doubt exists as to the value and the excellent results of this operation reference should be made to a large range of papers on this subject, the work of Samson and Burford (1947), Nicholson (1946), and Price Thomas and Cleland (1945) is of great interest and value

The surgery of retained missiles

The presence of a foreign body within the thorax is undesirable here as elsewhere and as a general rule fragments over 1 cm. in size should be removed whenever possible This may be a counsel of perfection, but since the operative risk in most instances is extremely



(*a*)



(*b*)

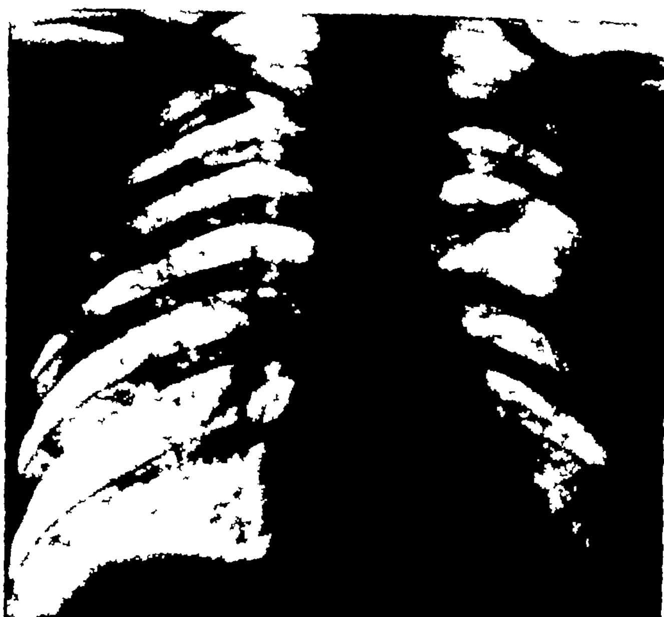


(c)

FIG. 3 3

(*a*) Thoracotomy for infected, partly clotted and organized haemothorax.
(*b*) After the decortication
(*c*) The wound after closure and the provision of under water sealed temporary drainage
(By courtesy of Lt-Col Frank Nicholson R A M C)





(a) (b)

FIG 23 6

(a) Radiograph of chest after penetrating gun shot wound
The left lung is completely collapsed and held down by an organized haemothorax

(b) The same patient three weeks later after thoracotomy and decortication
(By courtesy of Lt -Col Frank Nicholson, R A M C)





(a) (b)

FIG 23 7

(a) Gun shot wound of left chest showing a typical clotted multilocular haemo pneumothorax
(b) The same patient three weeks after thoracotomy and decortication

low and the late complication rate high removal was frequently carried out in the late war Even in the early stages severe complications may be seen in a series of 208 cases of retained intrathoracic missiles some severe complications were noted in the first six weeks as follows 2 deaths from haemoptysis 10 empyemata associated with peripherally sited lung missiles 10 small abscess cavities around intrapulmonary fragments, and 12 empyemata associated with pleural missiles In the same series several recurrent pericardial effusions and mediastinal abscesses were due to retained missiles The late complications may be traumatic lung abscess bronchiectasis or empyema (Fig 23 8)



(a) (b)

Fig 23 8

(*a*) Bullet in right upper lobe

Wound inflicted six years previously repeated small haemoptyses for month before this radiograph as taken. There i a small abscess cavity around the bullet which was removed nd the abscess ca ity was obliterated by suture ith relief of ll symptoms.

(*b*) Bullet in right upper lobe

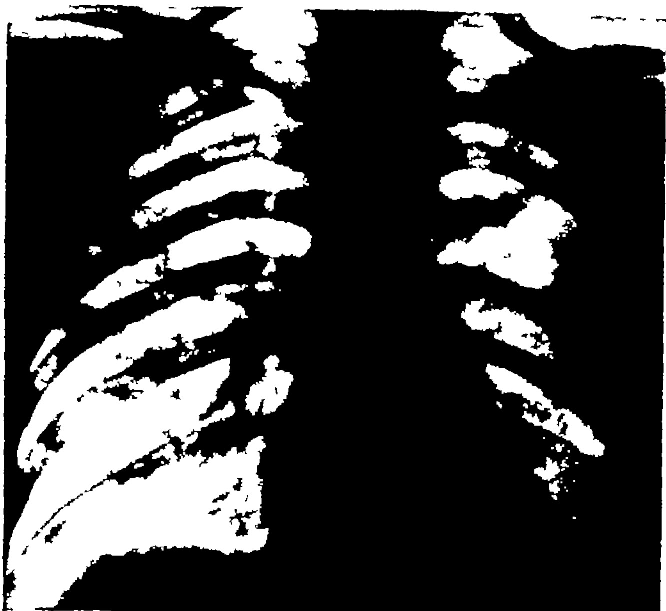
A track can be seen leading to the bullet

(By courtesy of Lieut -Col Frank Nicholson, R A M C)

The removal of foreign bodies from the lung and pleura presents no technical difficulties if the pre-operative localization has been exact with reference to fissures and lobes being far more important than the study of bony localizations since these are of little value once the pleural cavity is widely opened The foreign bodies in the lung are easily palpated unless surrounded by haematoma formation in such instances localization is usually possible by the use of a needle and by radiological screening in the theatre The missile track in the lung is often palpable because of the solid core of effused blood such tracks are often identifiable on the pre-operative radiograph (Fig 23 8 (*b*))

The outstanding contribution of Harken (1947) to the surgery of retained missiles in or near the heart has been referred to in Chapter 13





(a) (b)

FIG 23 6

(a) Radiograph of chest after penetrating gun shot wound
The left lung is completely collapsed and held down by an organized haemothorax

(b) The same patient three weeks later after thoracotomy and decortication
(By courtesy of Lt Col Frank Nicholson, R A M C)





(a) (b)

FIG. 23 7

(a) Gun-shot wound of left chest showing a typical clotted multilocular haemopneumothorax
(b) The same patient three weeks after thoracotomy and decortication

low and the late complication rate high removal was frequently carried out in the late war Even in the early stages severe complications may be seen in a series of 208 cases of retained intrathoracic missiles some severe complications were noted in the first six weeks as follows 2 deaths from haemoptysis 10 empyemata associated with peripherally sited lung missiles 10 small abscess cavities around intrapulmonary fragments, and 12 empyemata associated with pleural missiles In the same series several recurrent pericardial effusions and mediastinal abscesses were due to retained missiles The late complications may be traumatic lung abscess bronchiectasis or empyema (Fig 23 8)



(a) (b)

Fig 23·8

(a) Bullet in right upper lobe

Wound inflicted six years previously repeated small haemoptyses for a month before this radiograph was taken. There is a small abscess cavity around the bullet which w removed and the bscess cavity was obliterated by suture with relief of all symptoms

(b) Bullet in right upper lobe.

A track can be seen leading to the bullet.

(By courtesy of Lieut -Col Frank Nicholson, R A M C)

The removal of foreign bodies from the lung and pleura presents no technical difficulties if the pre-operative localization has been exact with reference to fissures and lobes being far more important than the study of bony localizations since these are of little value once the pleural cavity is widely opened The foreign bodies in the lung are easily palpated unless surrounded by haematoma formation in such instances localization is usually possible by the use of a needle and by radiological screening in the theatre The missile track in the lung is often palpable because of the solid core of effused blood such tracks are often identifiable on the pre-operative radiograph (Fig 23 8 (b))

The outstanding contribution of Harken (1947) to the surgery of retained missiles in or near the heart has been referred to in Chapter 13

Lung abscess

Lung contusions were seen frequently in the last war. They represented areas of effused blood and of oedema fluid; they rarely broke down into abscess cavities and those that did almost invariably responded to antibiotic therapy. Abscess cavities, usually without the features of real lung abscess, were sometimes seen around retained lung foreign bodies being more noticeable if the fragment concerned was a portion of in-driven rib. The treatment of such abscesses was removal of the foreign body, obliteration of the space by suture and antibiotic therapy. They had none of the malignity of true lung abscess. In 1,000 war wounds of the chest 32 lung abscesses were seen, 13 around lodged foreign bodies and 19 without retained missiles.

Pleurobiliary fistula and chylothorax

Thoracic wounds or trauma may be followed by the presence in one or both pleural cavities of bile or chyle, the former being by far the commoner.

Bilothorax. In over 1,000 consecutive thoracic wounds seen at a Base Hospital, seven had bile in the right pleural cavity following thoraco-abdominal wounds that had involved the liver. In all instances the diagnosis was unsuspected until the chest was aspirated for a supposed haemothorax. In spite of careful aspiration and penicillin therapy all these patients developed empyema which required drainage. This is of some interest in view of the short-lived fashion many years ago of attempting to sterilize empyemata by the injection of bile salts. These seven patients all recovered uneventfully.

Chylothorax. In a considerable war experience I only saw one traumatic chylothorax; this followed a bayonet wound of the lower thorax. Surprisingly chyle was found in both pleural cavities and accumulated so rapidly that bilateral intercostal drainage was employed. The patient died of inanition rapidly; at autopsy the thoracic duct was seen to be severed. Undoubtedly thoracotomy should have been practised in this patient, who had, however, other wounds and was critically ill on admission.

Etiology of chylothorax. About half of the reported instances of chylothorax have been attributed to injury,* the result of direct or indirect violence of which the most important seem to be violent hyperextension of the spine; the other half complicates malignant disease which involves the posterior mediastinum or the retro-peritoneal area, most usually in the shape of glandular compression or lymphomatosis or secondary carcinoma. Since 50 per cent of patients with chylothorax die from inanition (Meade *et al.* 1950) surgical relief by tying off the thoracic duct should always be considered.

The thoracic duct may be damaged in the thorax by injury or surgical operations, or torn as the result of injuries involving violent movements of the spine. Injury to the thoracic duct in the neck has provided many examples and ligation has usually been successful. In thoracic surgical operations the duct, or branches of it, may be damaged especially during the course of an extra-fascial apicolysis combined with upper thoracoplasty for tuberculous cavities. A large amount of chyle pours into the wound; when this happens the wound should be re-opened and the duct ligated; usually the second stage of the thoracoplasty can be executed at the same time. In the writer's knowledge this has been done on four occasions, one in his own practice.

It is strange that damage to the thoracic duct and its tributaries does not often complicate such radical operations as oesophagectomy; it is a rare complication of trans-thoracic

* If lymphangiectasis is present in the mediastinum quite a slight injury may precipitate rupture. I have seen this once, and know of another case operated upon by Dr [illegible] of Montevideo.

thoraco-lumbar sympathectomy for hypertension During the course of Blalock s operation for subclavian pulmonary artery anastomosis chyle may be seen exuding from a lymphatic duct after the left subclavian artery has been mobilized but no complication follows the immediate ligation of these channels

Clinical features of chylothorax With rupture of small tributaries of the duct symptoms may be slight the diagnosis being made unexpectedly after aspiration for a suspected pleural effusion occasionally a diagnosis of chylothorax may be made on the macroscopic appearances only of milky white fluid when the case in fact is one of pseudo-chylous effusion due to chronic inflammation in such patients the fat content of the fluid is low Nor does the administration of Sudan III lead to its recovery in the urine as occurs in true chylothorax with chyluria (Fletcher, 1930)

In more serious lesions the continuous loss of chyle with its fluid protein and fat content may lead to dehydration and starvation The presence of chyle though apparently not leading to infection causes a gross pleural reaction which becomes greatly thickened and covered by an exudate which leads to loss of chest wall and lung function. The lymphocytes and eosinophils in the blood showed a notable fall

Treatment This has been well described by Meade and others (1950) The first attempt at treatment should be by aspiration as half of the recorded cases have been arrested by this measure If aspiration fails to decrease the daily escape of chylous fluid into the chest closed drainage should be employed with the aim of producing rapid lung re-expansion If this second method fails surgical exploration is essential and should not be delayed for more than one to two weeks The main duct is best sought through a left lower thoracotomy as it lies between the aorta and the oesophagus at the level of the diaphragm The patient should have a fatty meal four hours before the operation as this increases the flow of chyle and its detection from the leak will be easier

The metabolic derangements caused by the chylous loss is best met by a high protein and fat diet the intravenous re infusion of aspirated or drained chyle may be dangerous because of the risks of anaphylaxis

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PART VII

THORACO ABDOMINAL SURGERY

INTRODUCTION

Fortunately or unfortunately no statutory body has attempted to define the scope of thoracic surgery one cynic has said that the field extends from the third cervical to the third lumbar vertebra! If this be true it would be better to speak of regional surgery rather than the surgery of systems and it would be quite as illogical to restrict the thyroid or abdominal surgeon to the reaches of the neck or abdomen as to forbid the thoracic or abdominal surgeon to proceed beyond the outlet or inlet of the thorax In practice if a surgeon has mastered the main details of abdominal surgery is proficient in the endoscopic examination of the gullet and tracheo bronchial tree and is capable of managing both abdominal and thoracic complications such as paralytic ileus electrolyte and fluid imbalance or collapse of a lobe of the lung pleural effusion or empyema he tackles the problems of thoraco-abdominal surgery The major complications of this branch of surgery are often thoracic and perhaps for this reason much of this surgery finds its way to thoracic clinics it is exacting work that demands a great deal of concentration and is time-consuming to a degree Adequate pre-operative and post-operative measures influence the results more perhaps than in any other branch of surgery

The diaphragm is no longer a barrier to the abdominal or thoracic surgeon its easy exposure section and repair present no technical difficulties and access to the infra-diaphragmatic compartments need not be inadequate The exposure of the cardia the upper half of the stomach and the spleen by a purely abdominal approach is often unsatisfactory hazardous and cramped and although lesions of these areas can be dealt with by upper laparotomy there is no need for poor exposures when the condition demands a clear demonstration If thoraco laparotomy is used post-operative attention must be divided equally between the care of the abdomen and the thorax Thoracic complications are avoidable if the normal physiology is restored at the end of the operation in practice this is achieved by effecting complete lung re-expansion as early as possible fortunately the factors that impede this namely pneumothorax atelectasis and pleural effusion, are detectable and correctable This will require constant radiological control commencing preferably in the operating theatre at the end of the operation so that the patient returns to the ward with the lung fully re-expanded and aerated often encouraged by bronchoscopy and aspiration of air from the pleural cavity A radiograph taken in the ward on the first post-operative day is essential whatever the physical signs and clinical condition of the patient on this radiological information adjustment of any drainage tube used aspiration of air or fluid or bronchoscopic suction for atelectasis can be conducted. In the absence of readily available radiological facilities thoraco-laparotomy is dangerous and ill advised The maintenance of the patient in correct fluid and electrolyte balance will prevent many of the abdominal metabolic and cardio respiratory complications

Some indications for thoraco-laparotomy

A consideration of the war-time approach to wounds of the left chest and the upper left quadrant of the abdomen showed the benefits of thoraco-laparotomy wounds of the lung, diaphragm, spleen, stomach and splenic flexure of the colon were more adequately dealt with by a single combined incision than by a purely abdominal or thoracic approach, and such an exposure has completely ousted the use of two separate incisions If thorough exposure is needed there can be no objection to a transpleural approach now that adequate anaesthesia and thoughtful post-operative chest care are available

In civilian surgery, certain lesions can only be approached with any degree of satisfaction by thoraco-laparotomy and typical of this group is cancer of the cardio-oesophageal junction, which can be dealt with radically only by this combined route For ease of approach thoraco-laparotomy is preferable in many instances for splenectomy, adrenalectomy carcinoma of the stomach, a few types of highly placed gastric ulcer, especially when these are sited in a thoracically placed loculus of stomach, the performance of an anastomosis between the portal vein and the inferior vena cava in the treatment of portal hypertension and for diaphragmatic hernia In many of these exposures the approach need only be transpleural and trans-diaphragmatic without the full extension of the incision across the upper abdominal musculature, and the costal cartilage framework

Care in closure of the diaphragmatic incision

It is clear that faulty closure of even the smallest incision may be followed by disastrous herniation, if knuckles of colon or small intestine become strangulated For this reason, the suture should be meticulous, two layers of interrupted silk or linen thread being used.

CHAPTER 24

SURGERY OF CARDIO-OESOPHAGEAL OBSTRUCTION AND THE UPPER THIRD OF THE STOMACH

Confronted with the problem of lower dysphagia the surgeon must keep an open mind on the suggested pathological basis of the lesion until radiological oesophagoscopic and histological evidence is available as a check on clinical impressions However tempting it may be to regard a patient s history and symptoms as classically those of cardiospasm this diagnosis may be dangerous even when radiological appearances seem typical until an oesophagoscopic examination has been performed. It is easy to demonstrate radio graphs apparently typical of cardiospasm in which oesophagoscopy has revealed a carcinoma of the oesophagus above or below a typical area of achalasia spasm

Malignant obstruction at the cardia may be due to oesophageal squamous carcinoma (which gives better post-operative results) or to adeno-carcinoma of the stomach both cancers spread upwards and downwards so that the gastric type chiefly by submucous spread involves the oesophagus and the oesophageal type frequently extends chiefly by lymphatic spread along the lesser curvature of the stomach The results of local oesophago gastric resections followed by oesophago-gastrostomy (see page 472) in which the greater curvature is used as a tube will be better in oesophageal cancer than in gastric tumours where the lymphatic spread is early and extensive Because of this difference in pathology Allison has advocated total gastrectomy for the second group of cases Gastric carcinoma in this area is notoriously silent until dysphagia develops the earlier symptoms of anaemia indigestion and loss of weight though slight indicate the need for radiological and endoscopic examination.

The thoraco-laparotomy incision

Although not confined to the left side this approach is the one applied most commonly a modified right-sided one being employed for the operation of porto-caval anastomosis for the relief of portal hypertension (Satinsky 1950) or the exposure of the right suprarenal gland Moore (1955) has described a right thoraco-abdominal incision for thoracic oesophagectomy

The choice between opening the abdomen or thorax first is not academic but depends on pre-operative decisions if a palliative or radical gastrectomy is being undertaken for a gastric cancer without dysphagia the abdomen is opened first for evidence of opera bility or non-operability through this incision the liver glands and peritoneal spaces are searched for metastases that may proclaim inoperability once resection has been decided upon the abdominal incision is continued along the line of the eighth or seventh rib to provide a full abdomino-thoracic approach If however the aim is to correct dysphagia in a one-stage operation as advised by Allison (1949) the full thoraco-laparotomy approach is employed from the start if the condition found is amenable to resection the radical operation is commenced if the growth is irremovable dysphagia can be relieved by partial excision followed by oesophago-gastrostomy oesophago-colo or jejuno-gastrostomy or by oesophago-jejunostomy (see Chap 19)

Pre-operative measures and anaesthesia Many of these patients are elderly emaciated

and toxic and ample time is needed for pre-operative measures in hospital The first step is often to restrict solids by mouth even if swallowing them is possible a fluid diet will provide calories and vitamins more readily than unhappy attempts at forcing solids, a considerable variety of flavours can be used and commonly a gain in weight is achieved After each fluid meal the oesophagus must be washed through with water drinks if there is partial cardio-oesophageal obstruction

Oral hygiene for dental sepsis may involve dental extractions and the removal of tartar frequent mouth washes and oral antibiotics are used If teeth have to be extracted the operation should be delayed until the gums are healthy and clean

The anaemia and disturbance of the plasma proteins consequent on the effects of dysphagia (accentuated by the changes that follow a carcinoma of the stomach if this is the site of the growth) are best corrected by blood transfusions in the pre-operative period Plasma may be selected in spite of the risks of serum jaundice, but intravenous amino acids have been of disappointing value Pre-operative chest exercises are used with caution and not pressed vigorously until the other pre-operative measures have produced a reasonable improvement Iron is given by mouth in addition to the administration of vitamins the need for extra vitamins is clear because the storage of these in the tissues has been greatly depleted as the result of deficient intake or failure to be absorbed in patients with gastric carcinoma their need in the post-operative phase of healing is too well known to require further mention If the patient is in negative water and electrolyte balance, usually the result of vomiting, or gastric aspiration, the administration of appropriate intravenous solutions is essential Systemic penicillin (half a million units twice a day) is started two days before operation

Anaesthesia Allison (1949) has advised certain measures to prevent post-operative complications, the chief being the prevention of oesophageal contents spilling into the tracheo-bronchial tree during the induction and maintenance of anaesthesia, and when the patient's position is being altered at the end of the operation Under pentothal and curare the oesophagoscope is passed and the contents of the gullet are aspirated A tampon is placed below the crico-pharyngeus muscle to avoid all risk of upward spill After the pharynx and nose have been aspirated carefully a pharyngeal airway is introduced and carefully packed off Anaesthesia is maintained by pentothal, curare and oxygen with occasional assistance from anaesthetic agents delivered through a perfectly fitting face-mask, so that the lung can be inflated as much as desired during the operation The need for an intratracheal tube, which may damage the mucosa and lead to tracheal infection during a long operation, is dispensed with if the vocal cords are relaxed by the use of curare Most surgeons, however, use such a tube

Throughout the long operation the anaesthetist must prevent atelectasis of any area of the exposed lung as this adds to the burdens of the patient during and after the operation While the oesophagus is being dissected in the mediastinum the inflated lung can be held away by an assistant to provide satisfactory exposure

At the close of the operation and before the patient is turned from the lateral to the dorsal position the swab in the oesophagus is removed and both oesophagoscopic and bronchoscopic aspirations are done in addition to a careful toilet of the pharynx and upper respiratory passages, as considerable secretion will have accumulated during the necessarily lengthy operation

At the end of the operation the patient should be showing some normal reflexes. He is returned to the ward with a B L B oxygen mask in position , with the modern type of light anaesthesia the patient regains consciousness in the theatre and can usually be

propped up if the blood pressure is maintained Throughout the operation a slow blood drip transfusion is maintained

Thoraco-laparotomy

The best access is provided if the full classical lateral thoracotomy position is adopted and the compromise position with the patient lying tilted posteriorly on the assumption that this allows a wide abdominal field is undesirable and based on a faulty impression that it provides better access to the duodenal end of the stomach An oblique incision across the whole of the left rectus muscle and if need be of the right one crosses the left costal margin to meet the eighth rib which is then resected along its entire length this provides an ample exposure after the diaphragm has been split at right angles to the line of the original wound down to and including the oesophageal hiatus If the patient is in a posteriorly tilted position the rib resection tends to be inadequate and calls for the use of unnecessarily heavy rib retraction If the full incision is employed exposure is made without the need for retractors When the diaphragm has been divided freely it is an advantage to stitch temporarily its edges to the parietal muscles of the thoracic cage and of the abdominal wall the sutures are haemostatic their use increases the width of the wound and the temporary attachment of the right flap of the diaphragm steadies the muscle and prevents kinking and obstruction of the inferior vena cava (Allison)

Radical total gastrectomy

By this procedure (Allison 1949) the whole of the stomach a portion of the lower oesophagus the spleen the left half of the body of the pancreas and a wide lymphatic field are resected *en bloc* At the time of writing it is clear that radical gastrectomy is losing rather than gaining in popularity because of the poor results viewed in terms of survival rates and of the poor post-operative nutritional states The invasion of nearby lymphatics by tumour is almost constant as the diagnosis of gastric carcinoma is rarely made in an early stage in 1949 Allison reported that in all his resection operations for malignant cardio-oesophageal obstruction no case was presented without post-operative histological evidence of malignant deposits in the lymphatic glands Because of gross spread many cases will be beyond the hope of cure and then palliative resection oesophago-gastrostomy or oesophago jejunostomy may be all that is possible

The oesophageal exposure The oesophagus lies in a tunnel between the pericardium and the aorta and is covered by mediastinal pleura loose areolar tissue and the ligamentum latum pulmonis These tissues are divided freely and the oesophagus elevated from its bed together with both the vagal nerves and held upwards by encircling tapes If the growth is invading surrounding tissues their removal is required and this may entail opening into the right pleura this has no adverse physiological effect if adequate lung inflation is maintained Any such opening is closed temporarily by a moist saline pack when the oesophagus has been lifted forwards by an encircling linen tape The oesophagus is cleared well down to the oesophageal hiatus which may require excision if invaded by growth as is commonly the case

Mobilization of the spleen If the tumour is operable the dissection is carried behind the lesser sac so that the stomach can be lifted forward with its associated lymphatics The spleen is mobilized by dividing the peritoneum on its lateral surface starting through the lieno-renal ligament and carrying the incision upwards to the left limit of the oesophageal hiatus With the spleen held forwards and upwards the tail of the pancreas is cleared from the posterior abdominal wall and is divided just before the inferior mesenteric vein

enters the splenic vein The pancreas has a rich blood supply and many vessels require careful ligation The cut surface of the pancreas is closed by fine interrupted thread or silk sutures After the splenic artery has been ligated and divided close to its origin from the coeliac axis, the corresponding vein is tied slightly to the left of its junction with the inferior mesenteric vein We have twice seen hepatic infarcts at autopsy, the result of clot formation in a splenic vein stump that was left too long (Symmers, 1950)

Mobilization of the stomach. Attention is now paid to the lesser curvature The tape around the oesophagus is pulled upon, and the right crus freely divided after division and ligation of the large vessels in it the lesser sac is opened by free division of the peritoneal ligaments and the dissection is carried as close to the liver as possible so that the lesser omentum will be resected The left gastric artery is secured and divided close to the coeliac axis after the hepatic artery has been defined and isolated

The great omentum is detached from its colon attachment, care being taken to work in the correct plane so that the colic vessels remain intact the omentum is detached as far as the pylorus and will be removed in one piece with the stomach

The pylorus is cleared and the duodenum, after isolation and ligation of the gastro-duodenal vessels, is crushed between two Schumacher's clamps and divided The duodenal stump is then closed The lesser omentum is dissected up to the porta hepatis and when the stomach is held away to the left, the portal vein, the hepatic artery and the common bile duct will be left with a minimum of areolar tissue around them The mass of tissue to be resected is then held upwards on to the upper edge of the wound in moist pads while the jejunal loop is prepared

Preparation of the jejunal loop A divided jejunal loop is preferred to an anastomosis of the oesophagus to the summit of an undivided jejunal loop, as the latter method is apt to be followed by regurgitation of duodenal contents into the oesophagus with the production of an agonizingly painful oesophagitis, which in one of my patients led to death five weeks after a successful gastric resection, even though an enteroanastomosis had been done between the two ends of the loop If the oesophagus has required a high division to ensure a wide enough excision above an upwards extension of the gastric growth, anastomosis to the summit of an undivided jejunal loop may be under undesirable tension

The jejunum is lifted well into the wound and its mesentery deliberately inspected the pattern of the jejunal vessels and the type of mesentery, short and stout, or long and lax, will determine the site for the division of the arterial arcades The division should go to the root of the mesentery where two or three primary radicals to the first arch can be divided, provided an adequate collateral circulation is available this can be estimated by following exactly the course of the blood flow that will be left once the mesentery and its vessels have been divided This stage of the operation must be done with the greatest deliberation and care and every effort made to avoid haematoma formation which may rapidly obscure the outlines of the vessels to be preserved A long jejunal loop must be fashioned so that it will lie without tension when drawn up into the posterior mediastinum The bowel is not divided until the necessary dissection, division, and ligation of the jejunal vessels have been completed The actual bowel section is best made between two light Schumacher clamps The proximal end of the divided jejunum is implanted later into the side of the divided jejunal loop lower down, and this is done without the use of clamps Throughout the whole of this stage of the operation a constant estimate of the viability of the jejunum must be made and the end of the isolated loop must be of good colour before it is passed as fit for the oesophageal anastomosis occasionally a cuff of it requires excision if the colour is doubtful

Oesophageal jejunal anastomosis At this stage the anaesthetist may be asked to decrease a little the inflation of the left lung but it must not be allowed to develop areas of ateleotasis it is better to have the inflated lung held away in a moist saline pad than to allow it to collapse for more than a few minutes

Through an opening in the transverse meso-colon the isolated jejunal loop is threaded upwards into the posterior mediastinum and care taken to see that it lies in its new bed without tension If the length is satisfactory it is withdrawn into the wound and its open end closed and inverted by two continuous layers of catgut (00) While it is outside the wound, the stoma for anastomosis with the oesophagus is prepared and after it has been



Fig 24 1—Radiograph showing an end to summit oesophago-jejunostomy after total gastrectomy Although condemned in the text this operation is favoured by some surgeons.

opened to a length corresponding with the size of the oesophageal lumen any bleeding vessels are picked up in mosquito artery forceps and ligated

With the mass of the stomach held upwards with a clamp below the proposed line of oesophageal section to prevent the regurgitation of septic stomach contents into the gullet the posterior wall of the oesophagus is incised Although a clamp above this line may prevent soiling from the oesophageal mucus it is better to rely on suction rather than to run the risk of damaging the oesophageal wall with one Two rows of interrupted linen or silk sutures (00 size or 000 silk) which approximate the muscular layers and mucous membrane to the corresponding jejunal tissue complete the posterior wall of the anastomosis of the oesophagus After the jejunal loop has been approximated without tension the anterior wall of the oesophago-jejunostomy is completed after the oesophagus has been cut completely across and the stomach removed the mucosal surfaces should be sutured by interrupted thread or silk stitches the knots of which lie within the lumen of the gut The suture is passed from within outwards on the oesophageal side and then over to penetrate the jejunal wall from without inwards and then tied (after R H Sweet) The anterior

suture line is reinforced by a series of fine sutures uniting the muscle of the oesophagus to the sero-muscular layer of the jejunum

The jejunum is then lightly sutured to the parietal pleura to relieve any tendency to post-operative dragging on the suture line and to increase the line of potential adhesion A final inspection of the anastomosis ensures that the jejunal loop is viable and of good colour If doubt is felt on this point it is better to re-make the anastomosis than risk a post-operative leak

The jejunum is attached by a few interrupted sutures to the edges of the hole in the meso-colon and the diaphragm is closed by a layer of interrupted sutures, the jejunum being sutured loosely to the re-fashioned hiatus opening, which must not be too tight



FIG 24 2—Total gastrectomy specimen

Removed from a man of 65 years who presented himself at the hospital with symptoms of severe dysphagia an extensive carcinoma of the stomach has invaded the cardio-oesophageal junction (specimen 18 cm) The spleen and part of the pancreas are to the right

The lung is fully re-inflated and the abdomen and chest wall closed in the usual layers, a tube being left *in situ* for underwater sealed drainage for 24 to 48 hours

When the dressings have been placed in position the table should be placed in the anti-Trendelenburg angle before the patient is turned on to the back to avoid the risk of jejunal regurgitation into the oesophagus which is no longer protected by an efficient diaphragmatic pinch-cock mechanism The bronchoscope is then passed to ensure complete clearing of the tracheo-bronchial tree and the nose and pharynx are sucked and mopped dry

A radiograph will show whether the lung is fully re-expanded The tube is connected to a water-sealed bottle and the patient retained in the theatre until he has regained consciousness and has an adequate cough reflex

Post-operative management In addition to the usual post-operative care of a thoracotomy, special problems with regard to correct fluid and electrolyte balance require constant attention Unless paralytic ileus develops, an in-dwelling duodenal tube is unwise as it may lead to oesophageal infection Fluids by mouth in sips are encouraged 36–48 hours

after operation the fluid requirements being met by intravenous infusions until that time Milk, tea coffee and soup are allowed for five days when the diet is added to in the shape of thin bread and butter lightly boiled eggs and jelly Normal solids are allowed on the tenth day

State of the patient after total gastrectomy

The nutritional and metabolic state of these patients continues to cause considerable anxiety and the problems have been studied by Brain (1951) The same problems are posed by patients after oesophagectomy and oesophago jejunostomy Appetite is slow to return and rarely becomes normal large meals cause discomfort and weight loss is the rule The most careful restrictions are necessary to prohibit large bulky meals frequent small meals of high calorie value are far better Diarrhoea is a common complication

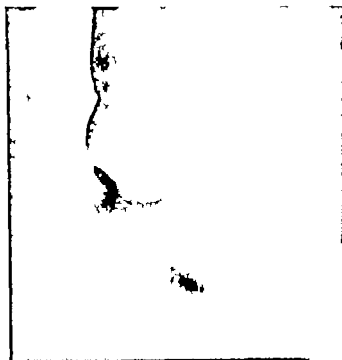


FIG 24 3—Radiograph of a man of 50 years with a hiatus hernia.
A gastric ulcer is present in the thoracic pouch of stomach and another large one is sited on the lesser curve.

Brain believes that the post-operative difficulties may be caused by difficulty of ingestion due to dyspepsia or dysphagia to defects in absorption disturbance of fluid balance and increased utilization of food Symptoms typical of the dumping syndrome noted occasionally after partial gastrectomy for peptic ulcer are seen comprising distension after food sweating palpitation and a feeling of faintness Dysphagia may be due to oesophagitis from regurgitation of intestinal fluid or due to vitamin B deficiency with a typical associated glossitis this may be relieved by nicotinic acid and riboflavine and partly anticipated by including these in the post-operative diet Defects of absorption are represented by steatorrhoea which is constantly present this is best treated by doubling the quantity of fat in the diet Allison gives clear instructions to patients after oesophago jejunostomy five small meals a day taken dry except for an aperitif such as a glass of sherry masticated well and eaten slowly extra butter cheese milk and cream A liver extract taken

daily and dilute hydrochloric acid (min X) to be taken in water before meals if diarrhoea is present

Less radical procedures

Many surgeons are opposed to radical gastrectomy operations because the five year survival rates are not high enough to offset the poor nutritional results and the immediate high mortality figures pyloric carcinoma is usually subjected to partial resection In the instance of cancer near the cardia a palliative resection followed by oesophageal anastomosis to a remnant of the stomach is frequently employed In these partial resections the division of both vagus nerves causes a pyloro-spasm, which may be the source of trouble in the immediate post-operative period The pyloric sphincter is therefore destroyed by a Rammstedt type of operation or by large dilators passed through the cut end of the remaining part of the stomach

Oesophago-duodenostomy Exceptionally the oesophagus can be anastomosed to the duodenum without tension · such an anastomosis is best made with interrupted unabsorbable sutures without clamps being used on either the duodenum or oesophagus At least two layers are required

Oesophago-jejuno-gastrostomy or oesophago-colo-gastrostomy These operations have a larger place in the treatment of benign fibrous strictures than of malignant obstructions They have been discussed in Chapter 19

Thoraco-laparotomy for gastric ulcer and benign tumours of the fundus

The chronic gastric ulcer of the lesser curvature is best resected by the classical abdominal gastrectomy , occasionally the ulcer of the saddle-shaped variety impinges on the cardio-oesophageal junction and may require a thoraco-laparotomy approach The combined operation however, is usually reserved for an adherent gastric ulcer in a portion of stomach herniated into the thorax In the radiograph (Fig 24 3) a gastric ulcer was present in a thoracic loculus of the stomach and a large ulcer, diverticular in appearance, is present high up on the lesser curvature this condition may be treated by excision of the ulcer through a thoracic approach, followed by repair of the hernia

A usual site for the rare large innocent tumour of the stomach of the nature of a fibro-myo-leiomyoma is the fundus access to this tumour, which can be resected locally, may be easier through the left leaf of the diaphragm than through the abdomen.

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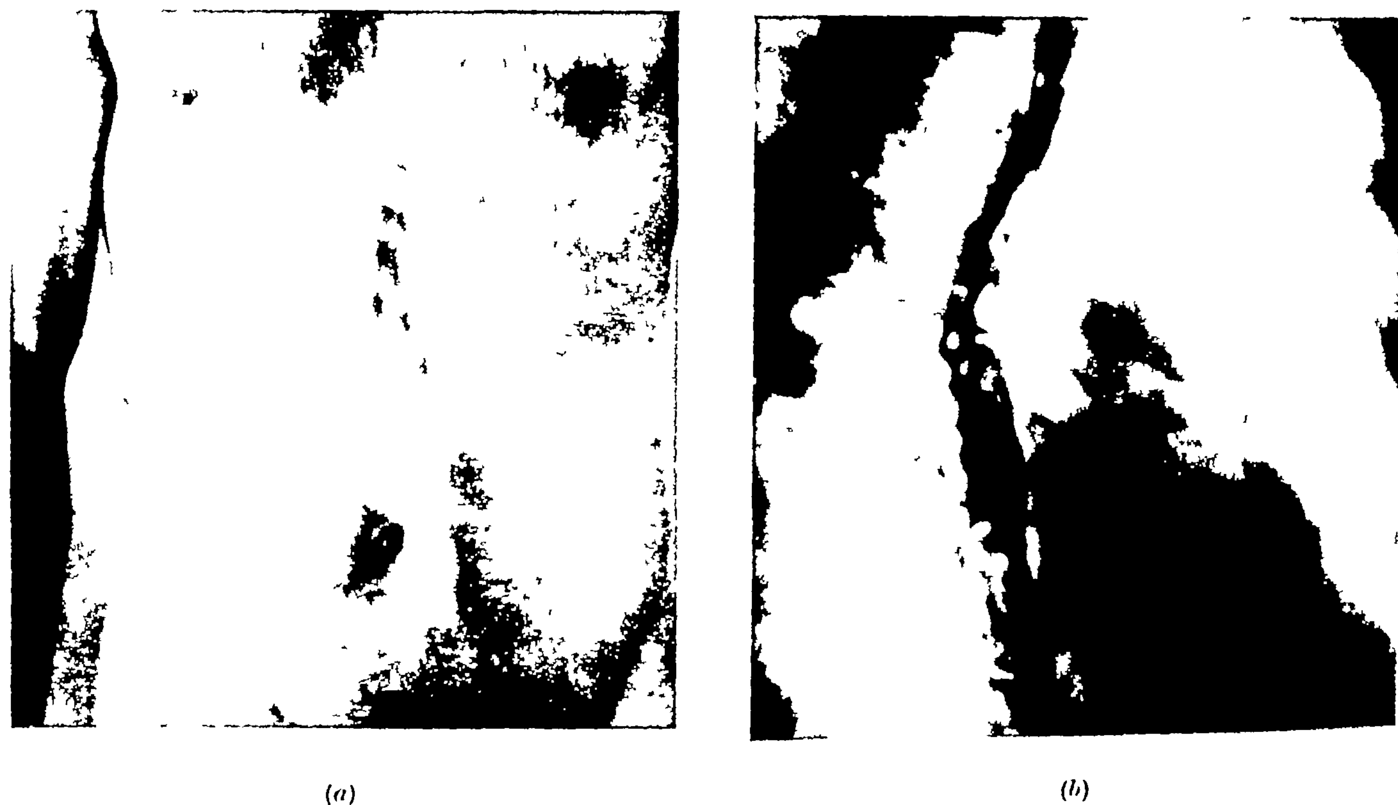
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CHAPTER 25

TRANS-THORACIC SPLENECTOMY: PORTAL HYPERTENSION

Trans-diaphragmatic splenectomy is not a surgical stunt It would be foolish to deny that removal of the spleen through an abdominal approach is a sound safe operation in most instances, but abdominal splenectomy is a difficult and sometimes hazardous operation when the spleen is large, vascular, and adherent to the diaphragm Technically whatever the size and condition of the spleen a trans-diaphragmatic approach is simple and provides the easiest and most direct approach to the splenic artery and veins and for the severance



(a) (b)

Fig 25 1

(a) Enlarged collateral abdominal wall vessels in a patient with severe portal hypertension

(b) Barium swallow with the typical appearances of oesophageal varices

of diaphragmatic adhesions As soon as the spleen has been exposed by the thoracic route it can be lifted well up into the wound and the securing of the pedicle is undoubtedly simpler than when the same manœuvre is being attempted at a distance in a somewhat far away space

The chief advantages of trans-thoracic splenectomy lie however in the lessening of post-operative complications In a follow-up of thirty-five trans-thoracic splenectomies there has been no example of subphrenic abscess of empyema or persistent left lower lobe atelectasis In twenty splenectomies collected at different hospitals, subphrenic abscess developed in two and there were two thoracic empyemata After thoracic splenectomy there is no tension on the wound and the patient is early and comfortably out of bed, which may be a factor in reducing the post-operative risk of venous thrombosis

In a book of this type it would be out of place to discuss the indications for splenectomy * In the series of thirty five mentioned above the spleen had been removed by the trans thoracic approach for lacerations due to gun-shot wounds acholuric jaundice splenomegaly



FIG 25-2 —A huge spleen partly covered by a gauze mop (note size in relation to surgeon s hand) has been delivered through a trans-thoracic trans-diaphragmatic wound.
Many adhesions to the diaphragm have been secured these would have provided formidable problems if tackled through an abdominal incision. The large vessels in the pedicle are seen in front of the surgeon s left hand.

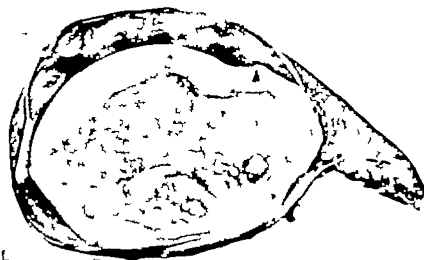


FIG 25-3 —A spleen greatly enlarged (20 cm.) by a contained hydatid removed by trans-diaphragmatic splenectomy

in portal hypertension purpura haemorrhagica, reticulo-sarcoma myelofibrosis and hydatid disease A few of the patients with portal hypertension have been subjected to anastomosis of the renal to the splenic vein but this operation is far less effective than porto caval anastomosis

The operation For a moderately enlarged spleen the approach is made through the bed of the resected ninth rib and the diaphragm is widely incised along the line of this incision

* A recent review of the indications for splenectomy by Edwards (1954) is helpful

the cut edges of the leaf being held apart as in the description given on page 79 (Fig 4 8) If the spleen is very large and likely to be difficult to deliver through a purely thoracic incision, the costal margin is divided as in the thoraco-laparotomy incision used for carcinoma of the stomach or of the cardia (see p 563) This is quite unusual

Any splenic adhesions to the diaphragm are divided and the spleen is then delivered into the wound and rotated to the right (Fig 25 2) The vessels in the gastro-splenic omentum are secured, divided and ligated as far away from the stomach as possible The peritoneum behind and lateral to the spleen is divided freely to expose the splenic artery and the splenic vein in the fold of the lieno-renal ligament these two vessels are secured by individual ligation and the attachments of the omentum to the lower pole of the organ divided and their vessels secured The tip of the pancreas is seen with great ease as the spleen is being held up and is quite secure from any accidental injury The diaphragm is closed by interrupted sutures and the chest closed with or without temporary drainage to a water-sealed system The management of any post-operative pleural effusion is along the usual lines

PORTAL HYPERTENSION

In portal hypertension, bleeding from the enlarged submucous veins in the area of the oesophago-gastric junction provides the main indication for surgical treatment Ascites due to hepatic cirrhosis has been treated by efforts to lower the portal venous pressure by porto-caval venous anastomosis, but few surgeons advocate its use for this complication Hypertension may be due to extra-hepatic or intra-hepatic causes Cirrhosis of the liver due to many different causes is the commonest cause (119 out of 142 cases Hunt, 1954) Extra-hepatic causes include congenital malformation or obliteration, thrombosis, infection and, rarely, pressure from neighbouring tumour formations

The adoption of surgical treatment is not advised lightly in view of a natural history which includes long survivals and intermission after the initial haemorrhage which may cover a period of twenty years , but many patients die from bleeding It is still too early to assess the long-term results of surgery but Walker (1954 and 1956) can point to the fact that of all his patients who survived an end-to-side porto-caval anastomosis and who had had no previous operations on the portal tract there has been no further episode of bleeding In a personal communication, he tells me that of 47 end-to-side porto-caval anastomoses 3 died after operation, 3 later and 41 have had no further bleeding His low mortality rate is notable

Two major operations are available for the treatment of oesophago-gastric bleeding (*a*) A large, artificially created anastomosis between the systemic and portal system , undoubtedly the best one is the portocaval anastomosis, but there may still be a small place for the spleno-renal venous anastomosis when there is no portal vein available (*b*) Direct operations on the oesophago-gastric area Of these, I prefer a limited oesophago-gastric resection in which the lower end of the oesophagus and the acid-bearing area of the lesser curvature is resected through a left thoraco-abdominal approach, continuity being restored by means of a tube fashioned from the greater curvature This not only disconnects the systemic and portal venous system but removes gastric juice which probably plays a large part in maintaining bleeding from erosions in this area MacPherson (1956) advocates oesophago-gastrectomy when other methods have failed Such operations naturally have no effect in lowering portal venous pressure

Splenectomy for portal hypertension is a bad operation the removal of the spleen before portal venography has been carried out is unjustified (see below) It is employed in those rare instances of splenic vein thrombosis producing splenomegaly and oesophageal varices

The injection of sclerosants through the oesophagoscope local operations on the varices of the oesophagus and temporary gauze packing of the mediastinal space and the oesophagus to produce fibrosis are not really effective measures

Methods of investigation

These include clinical haematological and biochemical investigations of liver function barium meal radiology to confirm the presence of oesophageal varices portal venography and the direct manometric estimation of portal venous pressure at operation a low serum albumin level (2 5 g per cent or lower) especially if this is lower than the globulin content a high serum alkaline phosphatase and a strongly positive Bromsulphalein test provide important danger signals

Portal venography The portal venous system can clearly be outlined by the method described by Walker and others (1953) After a rapid percutaneous injection of 30 ml of 70 per cent iodine contrast medium to the spleen radiographs are taken The pictures obtained will disclose the suitability or otherwise of the portal vein for anastomosis to the vena cava Such information may prevent an unnecessary exploratory operation

Venous pressures At the time of exploration the taking of venous pressures at different sites of the portal system will provide valuable information Hunt finds that the normal pressure varies between 50 mm and 160 mm of 3 8 sodium citrate solution Cirrhotic patients who have bled show the highest pressures while those with ascites alone may not have very elevated readings Bleeding is rare in patients with a pressure below 160 mm but Walker has seen it in several patients with pressures below this

Surgical procedures

The discovery of oesophageal varices might be regarded by some as an indication for surgery and as indicating the need for attempting to lower the pressure by porto-caval anastomosis My own view is that surgery is not indicated until bleeding has occurred in view of the uncertain course of the disease Since the operation carries a significant mortality rate medical measures should be given a full trial in the hope as in the case of cirrhosis patients that their liver regeneration may follow as some patients cease to bleed for many years after this has taken place If the patient can be tided over severe bleeding and venography indicates a good portal vein porto-caval anastomosis should be performed If the bleeding does not abate the patient may require urgent surgery and I believe then that oesophago-gastric resection is safer It may also be required if a porto-caval anastomosis has failed to prevent further bleeding

The operation of porto-caval anastomosis The incision first advocated by Satinsky (1948) gives a superb exposure of the structures that require exact dissection The ninth rib is resected in its entirety and the diaphragm split along the line of the incision With the patient lying on the left side the liver falls away and the inferior vena cava is readily exposed and dissected clear above the level of the renal vein the greatest hazard in its adequate clearing is the possible tearing of one of the thin walled lumbar veins The portal vein is seen lying anterior to it and the advantage of this exposure is that it is revealed directly as it lies behind the common bile duct Both the inferior vena cava and the portal vein are far more superficial in the wound than when a transperitoneal approach is employed

The portal vein is divided high up in the portal fissure, the hepatic end being tied after a Blalock clamp has been placed on its proximal end. To allow blood to flow along a large part of the lumen of the inferior vena cava, a part of the medial wall is pinched off in a Satinsky clamp: an end-to-side anastomosis of the portal vein is then made to the portion of vena cava held in the clamp, exactly as in the Blalock operation of subclavian-pulmonary artery anastomosis.

Partial oesophago-gastric resections. This operation is performed through a left thoraco-laparotomy incision as described for the surgery of carcinoma of the cardia (p. 563). The enlarged tortuous veins in the area provide a formidable surgical problem. If the spleen is still present it is removed at the same time. I have four patients who have survived four years up to date with no recurrence of bleeding. The operation is reserved for bad risk patients who appear to be dying in spite of massive blood transfusions.

Progress after porto-caval anastomosis. The careful follow-up of 56 patients by Walker (1957) provides information of great value or interest; 53 survived the operation. The most serious complication was the neuropathy; coma was the cause of death of the 3 patients who died in hospital. Nine other patients had episodes of encephalopathy. These complications usually develop soon after the patients return to home and often follow the eating of a large protein meal.

In most of the patients there is no detectable deterioration of liver function and the pre-operative leucopenia and thrombocytopenia slowly diminish. Following the venous shunt operation the diminution in size of the spleen is striking. Most of Walker's patients returned to normal living.

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CHAPTER 26

DIAPHRAGMATIC HERNIA

The increasing frequency with which gastric herniation through a defective hiatal opening is being recognized removes the diagnosis of diaphragmatic hernia from the list of odd, rare surgical curiosities The diagnosis and management of hiatal deficiency is a common surgical task far exceeding in importance other examples of diaphragmatic hernia It is largely an acquired condition though its frequency in infancy suggests a possibility that the muscular development of the right crus of the diaphragm may be faulty and even congenitally weak But other types of hernia are met with in surgical practice and Harrington s classification is a practical one

(A) Non Traumatic Hernia

1 *Congenital—at birth*

(a) Through foramen of Bochdalek (Pleuro peritoneal sinus)

(b) Through the oesophageal hiatus

(c) Through the foramen of Morgagni

(d) Through a deficiency of the left leaf of the diaphragm posteriorly in the region of the aortic hiatus

2 *Acquired*

(a) Through the oesophageal hiatus

(b) Through areas where the anlagen of the diaphragm fuse

(c) Through the sites of congenital hernia

(B) Traumatic

1 *Indirect* types that follow a crushing injury

(a) At any point of the diaphragm

(b) Through the oesophageal hiatus (usually with a sac) of the sliding type

(c) Through the leaf of the diaphragm (usually without a sac)

2 *Direct*

(a) The results of wounds by a missile or knife

(b) (i) The result of necrosis from an abscess below the diaphragm

(ii) The result of inflammatory necrosis in empyema as the result of long standing pressure of a drainage tube on the diaphragm (no sac)

Unusual types of hernia

These are largely the true congenital herniae with no sac in the thorax abdominal viscera being found in direct contact with the lung or pericardium. They depend for their existence on faulty embryological development of the diaphragm are always liable to strangulation except in gross defects such as the absence of large portions of the muscle and are curable surgically unless they reach hospital in the advanced stages of intestinal strangulation

Embryological considerations The separation of the coelomic cavity into pleural, pericardial and peritoneal sacs is complete in the 20 mm embryo The diaphragm is

developed from elements of the third and fourth cervical myotomes, of the septum ' versum, of the ventral mesentery, of the fusion of the dorsal mesentery with the p peritoneal membrane, and mesodermal elements which grow into it from the belly muscle masses The pleuro-peritoneal canal closes in the third month of intra-uterin The failure of fusion may be extensive (Fig 26 2)

If the various elements fail to fuse, persistent openings often containing portic bowel may be found, when such structures are in the chest they are not in a serou If the anlagen fuse incompletely, or weakly, the normal abdominal pressure may force through them and such herniae will have true peritoneal sacs the fusion in such ca deficient in mesodermal elements and the pleural and peritoneal elements alone will

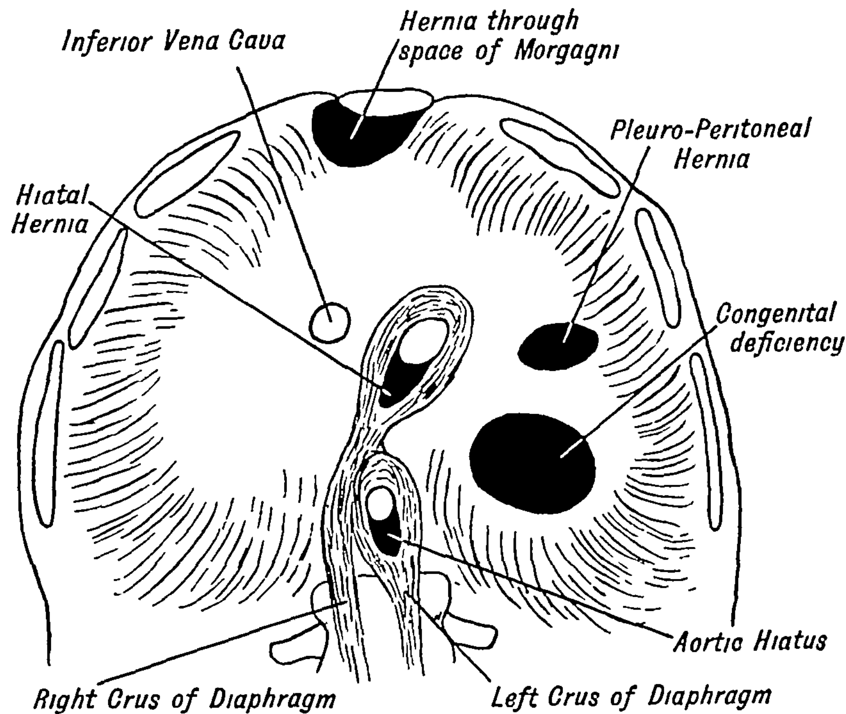


FIG 26 1 —Diagrammatic view of the under-surface of the diaphragm indicating the sites of herni

joined to become a thin, insecure area This faulty development may explain loca areas of eventration of the diaphragm (see Fig 26 10) It is therefore not prudent to that all true congenital herniae have no sac, though this will be so when the defe complete enough to leave a "canal" Usually this is the condition found at operat for strangulated diaphragmatic hernia in childhood, apart from the large oesopha hiatal deficiencies

Sites of congenital canal or weak areas (see Fig 26 1)

I The foramen of Bochdalek (Persistent pleuro-peritoneal canal)
II The retro-sternal hernia (foramen of Morgagni)
III Deficiencies of one dome

Congenital hernia

Though occasionally diagnosed and treated in middle age, most of the patients symptoms are met with in infancy and often die if surgical treatment is not immedi many not treated surgically die in the first year of life, as the result of strangulated bo in the foramen of Bochdalek or through an oesophageal hiatus

Symptoms Abdominal or thoracic symptoms may predominate In the abdom

group incessant vomiting with rapid resultant dehydration may suggest congenital hypertrophic pyloric stenosis or other intestinal tract obstructions Fortunately in the absence of a pyloric tumour a radiological examination will be carried out and a diaphragmatic hernia with characteristic features will be detected.

Occasionally absent breath sounds in the chest usually on the left side may be associated with a tympanitic note on percussion and the stethoscope may detect peristaltic sounds such was the case in the patient whose radiographs are presented in Fig 26 4.



(a) (b)

Fig 26-2 —Photograph of a post mortem on a man of 40 years. There is a gross defect of the left diaphragm.

(a) The defect in the diaphragm seen from below

(b) The heart is seen deficient in pericardial covering to the left of the phrenic nerve and is in direct contact with the left lung there has been almost complete failure of pleural, pericardial and peritoneal fusion processes.

The abdomen in spite of obvious clinical intestinal obstruction may be scaphoid and free from distension

Thoracic symptoms are usually dyspnoea and cyanosis gravely accentuated by the attacks of vomiting The explanation of these symptoms lies in the atelectasis of the compressed lung and the gross cardiac and mediastinal displacement The pulse and respiration rate will be high and pyrexia will accompany infection of the collapsed lung

Treatment However young the infant surgical relief and repair of the hernia is indicated and many babies have survived operation which is safer in the first 48 hours than a week later (Ladd and Gross 1941) The pre-operative measures include deflation of the stomach by an in-dwelling Ryle s tube correction of the dehydration by saline intravenous transfusions * oxygen tent therapy and antibiotics such as penicillin

Operative treatment The anaesthesia should be by the intratracheal route and may consist of small doses of ether and nitrous oxide with abundant oxygen curare or muscle relaxants are of help during the stage of reduction of the hernia and its repair The choice of incision is not always easy Undoubtedly the thoracic approach enables the

* It is easy to overhydrate infants who also retain salt readily (see page 434)

diaphragmatic defect to be closed more efficiently if the defect is through the foramen of Bochdalek, but the manipulative return of the intestines and solid viscera, such as the spleen, may be less easy than through the abdomen The post-operative period always seems easier after a thoracic approach and a thoracotomy is usually best, except for the relief of the huge bilocular oesophageal hiatal hernia occasionally met with (see Fig 26 3), or for the hernia through the foramen of Morgagni Typical examples may be cited

Obstructed gastric herniation through oesophageal hiatus

P W , aged 10 months Since birth feeding had been difficult with many episodes of vomiting She was weaned at 5 months From that time the attacks of vomiting became more troublesome



(*a*) (*b*)

Fig 26 3

(*a*) A bilocular herniation of the stomach through the oesophageal hiatus in a child of 10 months symptoms of persistent vomiting

Invariably in these patients whether adult or infantile the highest part of the stomach in the right chest is formed by the greater curvature of the stomach, which has therefore undergone a volvulus with the lesser curvature as the axis

(*b*) Post operative radiograph 5 months after reduction of the hernia and repair of the oesophageal hiatus

and repeated and there were frequent periods of severe constipation , at intervals the vomiting ceased completely for several days and the bowel habit became normal At the age of 10 months she was admitted to the Children's Hospital, Birmingham, in a serious condition of dehydration after two days of persistent vomiting The clinical condition was that of high intestinal obstruction without abdominal distension the child was undersized with a weight of 13 lb $5\frac{1}{2}$ oz (6,645 grammes) Peristaltic sounds were present in the abdomen no obvious abdominal cause for the obstruction being found a radiograph of the chest was taken after a small barium meal and revealed a large bilocular hernia (see Fig 26 3 (*b*)) Since the hernia was clearly through a very large oesophageal hiatus and involved both sides of the mediastinum, an abdominal approach was chosen

At the operation the pylorus was seen just below the left lobe of the liver, the remainder of the stomach being in the thorax which it had entered through a huge oesophageal hiatus The stomach was easily withdrawn into the abdomen after division of the left triangular ligament of the left lobe of the lung the peritoneal sac at the edge of the hiatus was freely divided, a large part of the sliding hernial sac being left up in the chest By means of interrupted linen thread sutures

(No 60) the defect in the right crus of the diaphragm was closed and the wall of the lower end of the oesophagus attached to the edges of the hiatus by a few further sutures

Recovery was satisfactory and the child has remained well and symptom free for the last six years (Fig 26 3 (*a*))

Strangulated diaphragmatic hernia through the foramen of Bochdalek (trans thoracic reduction and repair)

L. T aged 4½ months was admitted to the Children s Hospital Birmingham after continuous vomiting for two days the abdomen was distended and showed a typical ladder pattern of peri staltic waves The trachea and heart were grossly displaced to the right and loud peristaltic sounds were audible in the left chest A clinical diagnosis of strangulated diaphragmatic hernia was confirmed radiologically (Fig 26 4)



(*a*)



(*b*)

Fig 26-4

(*a*) Lateral radiograph of the chest and abdomen of an infant of 4½ months admitted with signs and symptoms of grave intestinal obstruction.

At operation the deficiency in the diaphragm was through the foramen of Bochdalek.

(*b*) A year after operation.

The child is well and symptom-free. The left leaf of the diaphragm remains paralysed as result of the left phrenic nerve crush employed to increase the size of the abdomen to receive the distended loop of intestine seen at operation.

Under intratracheal anaesthesia the left chest was opened plum coloured bowel was at once seen There was no sac present and the hernia was of the Bochdalek type With considerable difficulty the bowel which was just viable was returned to the abdomen after the left phrenic nerve had been crushed the left lung which was completely collapsed slowly re-expanded when the anaesthetic gas pressure was raised. The defect in the diaphragm was closed and the chest closed without drainage The child made a good recovery and is well seven years later though with a permanently paralysed diaphragm

Some difficulties in the treatment of strangulated or incarcerated diaphragmatic hernia in infants

The induction of anaesthesia may be dangerous because of the risk of regurgitant vomiting for this reason a tube should be passed down the oesophagus and gastric contents

aspirated continuously during the induction which should be carried out with the p in a propped-up position as soon as possible an intratracheal tube should be p

Difficulty may be experienced in reducing the distended bowel into the abd which has remained small when the mass of the intestinal tract has been in the t Ladd and Gross (1941) have recommended a two-stage operation this consists of m an abdominal incision which is closed by skin suture only, so that the abdominal ca temporarily enlarged , at a later date this deliberately created incisional hernia is rep In the post-operative care, lung re-inflation is encouraged by all means and this

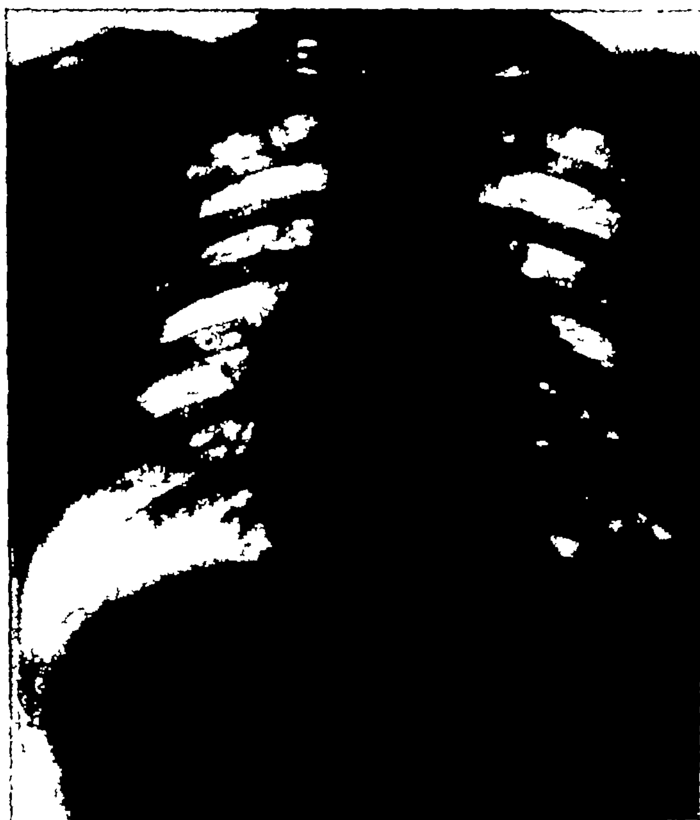


FIG 26 5—Radiograph of a man of 35 years admitted with an obstructed diaphragmatic hernia (foramen of Bochdalek)
Repaired trans thoracically

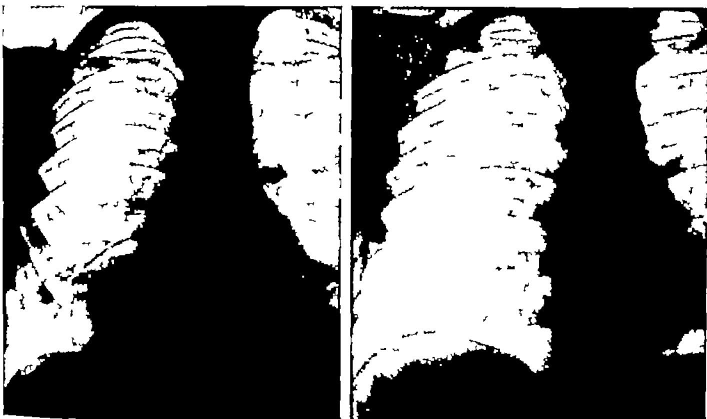
entails the aspiration of air from the pleural cavity at the closure of operation and wards as indicated The infant should then receive oxygen in the immediate post-ope period paralytic ileus and dehydration will be treated by continuous gastric suction intravenous therapy.

Strangulation of hernia through the foramen of Bochdalek

Obstruction or strangulation of this type of hernia may not follow until adult Fig 26 5 is a radiograph of a man of 35 admitted with an obstructed left diaphragm hernia the symptoms were those of high intestinal obstruction At operation there no sac in the left chest and the contents were those of small intestine loops which returned through the foramen and the diaphragm replaced with uneventful recover

Symptoms of congenital diaphragmatic hernia (excluding those through the oesophageal hiatus) in adult life

Although these herniae in infants and children are associated with a high mortality rate if not repaired surgically some patients survive to adult life or old age Exceptionally they remain asymptomatic and may be detected during the routine radiological examination of the chest when an air-containing viscus is seen. On the right side a herniation of the liver may develop and be regarded as a mediastinal or lung tumour Probably most thoracic surgeons have had the humbling experience of carrying out a right thoracotomy



(a) (b)

Fig. 26-6.—Herniation through the foramen of Morgagni before and after repair by the abdominal route (a) Pre-operative Note hernia to the right (b) After repair
Operation by Mr E P Scott Mason.

on the preliminary diagnosis of thoracic tumour and have been chagrined to find a diaphragmatic hernia (Fig 26 7)

The symptoms of the usual hernia of this type may include dyspepsia vomiting intestinal obstruction and cough with dyspnoea If the stomach is incarcerated haematemesis or melaena may develop as the result of congestion or from a surface erosion or true gastric ulcer (see Fig 24 3) This bleeding may be the cause of severe anaemia

Hernia through the foramen of Morgagni

This is uncommon and often symptomless a curious shadow is seen to the right of the cardiac shadow on the radiograph and may be mistaken for a thoracic tumour the usual contents are omentum and colon The investigation requires a barium meal follow through examination If repair is required for the relief of symptoms the abdominal approach is the best it may require division of the costal cartilage to assist in the cure

Diaphragmatic hernia of traumatic origin

The diaphragm, usually its left leaf, may be torn by the compression effects of crushing injuries or wounded by the tangential passage of missiles or of a knife. Such laceration may be detected during the operative treatment of thoraco-abdominal wounds, but not infrequently a hernia is present which may not cause symptoms until many years later, when those of gastric or intestinal obstructions develop. Patients wounded in the 1914–18 war are still being admitted occasionally with obstruction in such a hernia. The diagnosis is made on the history, the symptoms, the discovery sometimes of adventitious bowel sounds,



FIG. 26.7.—Lateral radiograph of right chest, mass radiography case

A barium meal showed no abdominal viscus in the chest. Thoracotomy revealed a large mass of omentum emerging through a hernia of Morgagni. (Mr Stevenson, Hill Top Thoracic Hospital.)

or auscultation of the chest and by radiological appearances. The repair and reduction of the hernia is usually not difficult through a thoracic approach which provides a good view for dividing any adhesions that might impede the return of the contents to the abdomen.

Eventration of the diaphragm

Apart from elevation and atrophy of the diaphragm after deliberate or accidental interruption of the phrenic nerve, a thin atrophied leaf may be present on the left side. The condition, known as eventration, is easily confused with diaphragmatic hernia as the symptoms and radiological appearances are similar; the eventration may involve the whole leaf or only part of it (Figs. 26.9 and 26.10). On radiological examination, in a true eventration it is usually possible to follow the entire length of the line of the diaphragm without any loss or break in its continuity (Reed and Borden, 1935). In differentiating the condition from a paralysis due to injury or disease of the phrenic nerve there is no true paradoxical

movement though the movement is greatly impaired In half of these patients a barium meal shows the classical picture of inversion of the stomach with the greater curvature lying underneath the diaphragm

When symptoms are present they are frequently those of diaphragmatic hernia though less in severity yet associated with more pain in some patients for reasons difficult to cite They may be quite symptomless If symptoms are considerable relief can be obtained by a trans thoracic plication of the atrophied leaflet At operation the deficiency rarely includes the whole diaphragmatic leaf Well-developed active muscle is found inserted into a very extensive thin aponeurotic central tendon the presence of this functioning muscle is an indication that the state is not due to faulty phrenic nerve innervation The



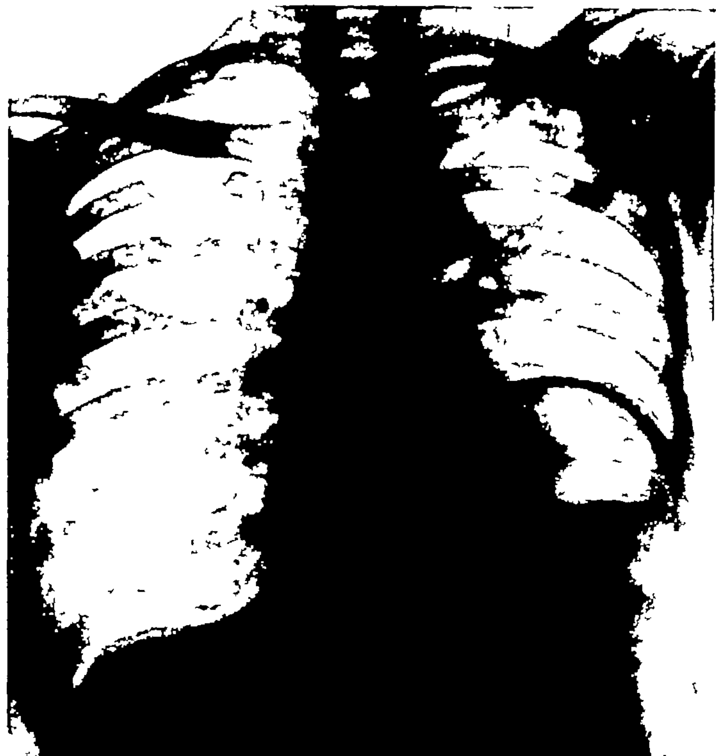
FIG 6·8 —Left-sided traumatic hernia which contained stomach and colon The patient had been severely crushed in car accident some months before this radiograph w taken

plication must be done thoroughly and it is advantageous to use all the slack central part of the diaphragm and not to excise any of it As much slack tissue as possible is lifted up and the base of the fold so elevated is sutured together the flat is then folded down and sewn if possible to tendinous tissue as near to good muscle as possible Evans and Simpson (1950) have given interesting details of eight patients with this condition Seven of them had symptoms and four were operated on

Herniation through the oesophageal hiatus (hiatal deficiency)

Anatomical and physiological considerations This condition represents the most important type of diaphragmatic herniation and requires fuller discussion than the conditions outlined in the previous section

In Chapter 19 page 440 an attempt has been made to discuss the mechanism at the gastro-oesophageal junction by which reflux of gastric juice into the gullet is prevented Whichever of the several factors is responsible for maintaining efficiency of the mechanism it is certain that the herniation into the thorax of that part of the stomach into which the oesophagus enters allows gastric fluid to reflux into the gullet and may cause symptoms the most serious of which are due to oesophagitis By no means all patients with a sliding

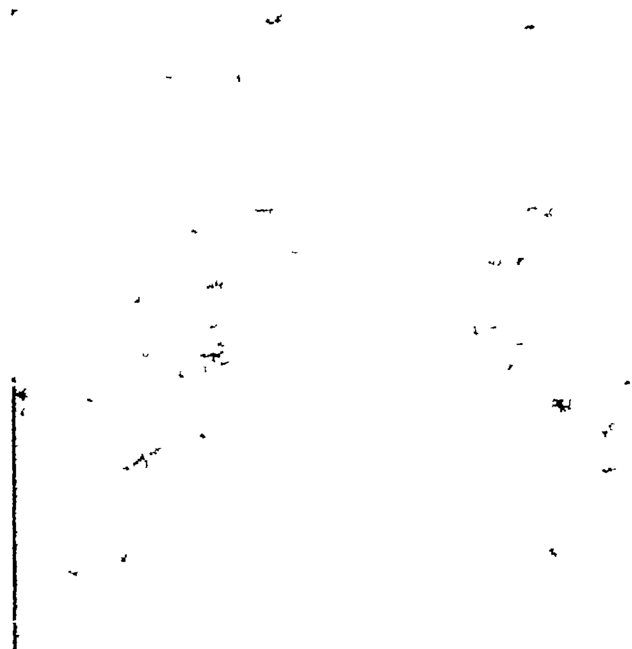


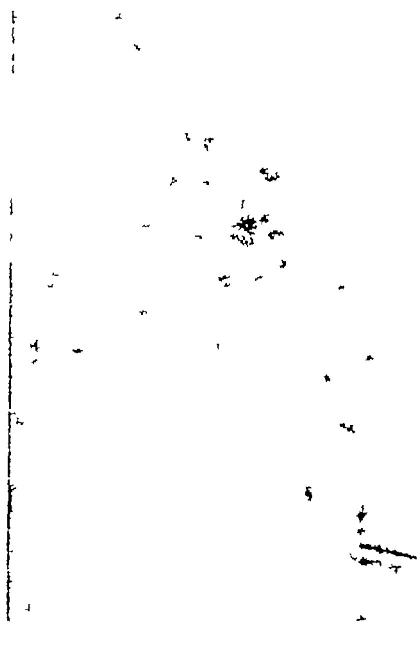


(*a*) (*b*)

FIG 26 9 (*a*) and (*b*) —Eventration of the left diaphragm in a woman of 48 years

Symptoms of epigastric discomfort, dyspnoea and pain in the left lower chest sufficiently severe to justify operative plication of the diaphragm There was no paradoxical movement on radiological screening (Patient of Dr J V R Philip)





(*a*)

FIG. 26 10 —A

On a postero anterior view the condition had bee[illegible] and the intact line of the diaphragm is well seen [illegible] t of Dr D J Loughran)

hiatal hernia develop oesophagitis if the hernia is para-oesophageal with the cardia in the abdomen reflux does not occur and the symptoms will be those of discomfort flatulence indigestion or palpitations Even with a hernia that allows gastric reflux oesophagitis may not develop as this depends on the quality of the digestive action of the juice and the temperament of the patient When a patient is referred for surgical treatment it is important that all concerned should know exactly what is the aim of any proposed surgery or whether in fact any should be employed Surgery may be essential because of severe obstruction of the stomach itself when incessant recurrent vomiting exists as in the usual type of hiatal hernia in which there is a volvulus of the stomach the so-called bilocular hernia (see Fig 26 3) for the relief of intolerable heartburn not relieved by conservative methods and due to oesophagitis after thorough radiological and oesophagoscopic examination in the hope of preventing ulceration and fibrosis of the oesophagus (not always a rewarding field) for some examples of haematemesis

If surgery is employed solely on the basis of radiological findings in a patient with oesophagitis or dysphagia serious errors may be made As an instance may be cited the problem in which a hernia accompanying the condition known as Barrett s ulcer (see page 441) has been diagnosed radiologically surgical repair of such a hernia will provide no relief at all as the symptoms are due to a true gastric ulcer in a gastric lined gullet In infants with undoubted reflux oesophagitis and a partial thoracic stomach surgical repair of the hernia is unlikely to succeed however meticulous the operative technique for perfect replacement of the cardia in the abdomen is rarely achieved A glance at Fig 26 12 indicates the difficulty of this problem in this infant of a few weeks there is already severe structural change in the oesophagus and the operative replacement of such a gastro-oesophageal junction into the abdomen without tension would be hard to achieve I believe that the treatment of such a condition in infants should be essentially conservative as the results are good (see page 587) This opinion has been reached after the performance of a considerable number of operations for this condition

Surgery however has an important part to play (*a*) in many hiatal herniae and (*b*) in relieving the stenotic effects of oesophagitis whether these be due to peptic ulceration of the true oesophagus (Allison s ulcer) or to an ulcer in gastric lined aoesophagus (Barrett s ulcer) (see Chapter 19)

Herniation of the stomach into the posterior mediastinum is common and is met with in three different groups

(*a*) Hiatal deficiency in infants leading to

(1) Obstruction or strangulation of the stomach and other parts of the alimentary canal (see Fig 26-3)

(2) Severe attacks of vomiting haematemesis and melaena in infants often followed later by oesophageal stricture formation

(*b*) Hiatal deficiency in adults often middle-aged women causing at first an unorthodox type of dyspepsia which may simulate cholecystitis gastric ulcer or coronary heart disease Less commonly but by no means rarely a long period of dyspepsia may be followed by dysphagia the result of oesophageal ulceration and stenosis (see Chapter 19)

(*c*) Hiatal deficiency in which part of the stomach herniates into the thorax but without any displacement of the abdominal portion of the oesophagus the entrance of which into the stomach retains its normal obliquity In this group the symptoms are usually those of distension and upper abdominal discomfort but without the sequelae of gastric reflux into the oesophagus. This type of deficiency is often classified as a para-oesophageal hernia (see Fig 26-19)

(*a*) **Hiatal deficiency in infants and children** (see also Chapter 19)

This is not a rare condition In 1949 and 1950 Astley, at the Children's Hospital, Birmingham, confirmed radiologically that it was present in 32 patients. 21 of these had severe hiatal incompetence without real stricture formation, 6 of these were diagnosed in the first fourteen days of life and 14 between the age of one month to 18 months There were 6 with definite stricture formation (8 months to a year) and 5 had "short" oesophagus without stricture formation

Much confusion still exists about "congenital" shortening of the oesophagus, haematemesis and melaena of the newborn, but the association between the two conditions is



FIG 26 11 —Radiograph (barium swallow) showing gastric hernia and spasm of oesophagus above it in an infant who died from vomiting and haematemesis
(See Fig 26 12 for autopsy specimen)

still frequently overlooked Over 150 infants have now been followed up at the Children's Hospital, Birmingham, who from early age had vomiting or haematemesis or melaena and who later developed a stricture and ulcer formation The true etiology of these conditions is the hiatal insufficiency which allows stomach contents to regurgitate into the oesophagus with the production of surface ulceration and may later be followed by a steady rise of the oesophago-gastric junction and of part of the stomach itself, into the thorax The stricture, which is at first quite low down, may reach as high as the sixth thoracic vertebra and many of these patients have been labelled as congenital short oesophagus or classed as the "ascending fibrosis" of Brown-Kelly the latter term is undoubtedly correct, but the true cause of the fibrosing process is often overlooked A true congenital shortening of the oesophagus occurs or may be lined by gastric mucosa, but even if the congenital deficiency is one of shortening of the oesophagus the hiatal mechanism is lost because the gullet enters the stomach without any obliquity and the preventive mechanism is absent

The importance of realizing the nature of the hiatal defect early in the disease would indicate that immediate steps should be taken to prevent the reflux of gastric juice into the

gullet *day and night* At the Children s Hospital Birmingham this is done by nursing the infant in a specially made plastor cast bed (Fig 26 13) usually vomiting ceases at once if it persists the feeds are artificially thickened The results have been good (Carre Astley Smellie (1952)) although undoubtedly a few proceed to stricture formation for which surgery is required

Operative repair on infants has not been uniformly successful Allison s operation which has been successful in adult patients often fails in infants because it is often impossible to reduce the cardio-oesophageal junction into the abdomen as the oesophagus is truly short or too thickened by fibrosis even in the first few weeks of life



Fig 26·12 —Autopsy specimen from an infant who had suffered from vomiting and haematemesis since birth

Note the early herniation of the stomach beyond the diaphragm, the loss of obliquity of the oesophageal entrance into the stomach and the erosion and ulceration of the lower end of oesophagus just above the folds of herniated gastric mucosa

Gastrostomy as a means of treatment fails because the stomach contents regurgitate after each feed and the vomiting is usually increased, not diminished. The development of oesophageal ulceration occurring so early in life when gastric juice is largely free from hydrochloric acid * indicates that some other factor in gastric secretion is responsible for the condition The ulcer seen in Fig 26 12 had the histological characteristics of peptic ulceration.

Clinical features of hiatal deficiency in infancy The early onset of vomiting with or without haematemesis and melaena is typical this may be severe enough to receive a diagnosis of hypertrophic pyloric stenosis or of duodenal stenosis but as mentioned elsewhere in the absence of a palpable lump surgical intervention for other unusual causes of alimentary canal obstruction will not be attempted without radiological investigation The diagnosis will be made if at some stage a radiological screening or photograph is taken

* Acid is present for 14 days then disappears, to re-appear at varying intervals

with the infant in a prone position, for the gastric reflux and the raised position of the cardia will be discovered

In some infants the first indication of the condition may be the passage of a typical melaena stool the features of collapse and dehydration are often manifest quite early, depending on the degree of vomiting and the difficulty of getting any fluid into the stomach A few of these infants die with the indefinite diagnosis of " haematemesis and melaena of the newborn " With careful treatment, which requires the constant use of a propped-up position and careful feeding, many of these infants do well and by no means all develop ulceration though the hiatal deficiency persists.

Treatment Some of these infants develop strictures, oesophagoscopic dilatation,



FIG 26 13 —Photograph of infant with hiatal hernia and oesophagitis being treated in a propped-up position in a plaster bed

combined with the constant adoption of a propped-up position, especially at night, the use of alkalis and great care in the feeding may produce considerable benefit at a later date major surgical procedures, as described below, may be essential

If surgical closure of the hiatal defect is to be effective it must be done before ulceration and ascending fibrosis have developed, but as already indicated the results to date have been disappointing The essential requisites for successful surgery are the reduction of the cardia below the diaphragm without tension, division of the peritoneal process that is in the thorax, rather in the nature of a false sac in front and to the sides of the oesophagus, the re-suture of the divided phreno-oesophageal ligament to the under-surface of the diaphragm and the approximation by suture of the divaricated limbs of the right crus (see Fig 26 20)

In fully developed lesions the progressive or pre-existing congenital shortening and fibrosis of the oesophagus make these steps impossible and the cardia cannot be replaced in the abdomen

If the operation is delayed until the oesophagus has shortened and stricture formation has commenced the emphasis should be on conservative treatment and the inevitable development of a stricture accepted This stricture may require oesophagoscopic dilatation or later call for major surgery (See Chap 19 page 444)

Three types of herniation through the oesophageal hiatus of the oesophagus exist

(*I*) *The typical sliding hernia* The cardia and part of the stomach both greater and lesser curvatures slide up into the mediastinum There is no complete peritoneal sac in spite of many descriptions to the contrary It is impossible to dissect out a sac as in indirect oblique inguinal lesions so that it could be tied off at its neck. There is a sac which covers the anterior and lateral aspects of the herniated portion of stomach which is devoid of peritoneum posteriorly The apex of the laterally and anteriorly placed sac consists of peritoneum and elastic tissue and is attached to the junction of the oesophagus and stomach (the phreno-oesophageal ligament) At operation this is the reliable guide to the position of the cardia The stomach is encouraged to slide upwards in fat people and commonly does so in pregnancy By allowing reflux of gastric juice it often causes heartburn and oesophagitis

(*II*) *Para-oesophageal hernia* This is a sliding hernia of the stomach but the oesophagus remains normal in length and is anchored in the abdomen It may become huge so that the whole stomach, a large amount of omentum and occasionally the colon may pass up into it Sometimes the stomach undergoes a volvulus and the greater curvature is then found to the right side of the mediastinum (bilocular hernia)

(*III*) *The mixed type* Both types described above co-exist with the cardia in the thorax In the gastric lined oesophagus the abnormal mucous membrane of the gullet is often accompanied by a hiatal hernia (see page 441) If the symptoms are due to ulceration of this gastric mucosa repair of the associated hernia will fail to relieve them

Symptoms in hiatal hernia in adults

The distension of the stomach by a meal in the subject with a normal oesophageal hiatus and a normally sited cardia, raises the level of the stomach gas bubble in the fundus and thus further increases the obliquity of the gastro-oesophageal junction

The area commonly called the cardia lies embedded in the mass of the crural muscles and there is no true abdominal portion of the oesophagus (Allison 1948) The contraction of these crural muscles during inspiration closes down the lumen of this part of the gullet and thus prevents the negative intrathoracic pressure sucking gastric contents up into it The key to this effective pinch-cock mechanism therefore lies in the obliquity of the oesophago-gastric junction and the effective contraction of the crural muscles The diaphragmatic muscle and the oblique angle of the gastro-oesophageal junction are not the only factors The significance of the mucosal valve of Dornhorst has been mentioned in Chapter 19 page 441

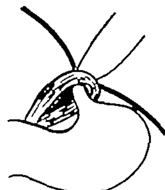


Fig 26·14 —Diagram of the right crural ring and its relationship to the cardio-oesophageal junction (after Allison)

A typical history produces a complaint of dyspepsia associated with distension after food pain high up in the epigastrium and often in the back at the level of the eighth to twelfth thoracic vertebra an uncritical approach to such complaints might suggest a diagnosis of cholecystitis and some of the patients in our

series have undergone cholecystectomy without relief, even when gall stones have been present Most of the patients with hiatal deficiency complain of heartburn and of regurgitation of bitter fluid into the oesophagus and occasionally into the mouth when they bend down to tie up shoe-laces some patients have had to abandon gardening because of the discomfort and heartburn caused by stooping Pain in the precordial area has been attributed in not a few to heart disease Alkalies usually fail to relieve the symptoms,



Fig 26 15



Fig 26 16

Fig 26 15—Oesophageal hiatal insufficiency

This radiograph shows extreme regurgitation when the patient is recumbent, there is no true gastric herniation and the cardia is at the normal level as proved by oesophagoscopy and radiological estimate Symptoms were severe and were relieved by Allison s repair (see text)

Fig 26 16—A fully developed oesophageal hiatus hernia with a large loculus of stomach in the posterior mediastinum

This was repaired and the oesophago gastric junction was readily replaced in the abdomen with complete relief of symptoms

a propped-up position in bed (usually on medical advice, after the correct diagnosis of hiatal deficiency has been made) may not provide relief in obese subjects drastic reduction of weight is probably the most important measure, sedatives are of value and frequent small meals are better than two large daily ones

If oesophagitis develops, retro-sternal pain is often severe, this pain not infrequently radiates up the neck into the mouth and behind the ears, anaemia and haematemeses are occasional features The diagnosis of many of the patients in the group has been peptic ulcer of the stomach or duodenum, cholecystitis, hyperacidity, cardiospasm or heart disease Many of these patients began their symptoms during pregnancy or developed them in the forties, when they began to put on weight

Diagnosis As the physical signs are indeterminate the only one of value being the occasional auscultation of peristaltic waves in the chest diagnosis will rest on the suspicion raised by a history of unorthodox upper abdominal dyspepsia associated with heartburn regurgitation and of pain in the areas mentioned and its confirmation by careful radiology The essential radiological appearances will be brought out by screening the patient in the





FIG 26-17 FIG 26-18

FIG 26-17—Large oesophageal hiatus hernia

This obvious herniation was only visible when the patient was placed in the recumbent position after barium had been swallowed into the stomach

FIG 26-18—Oesophageal hiatus hernia in a woman of 60 years with severe symptoms of 15 years duration followed by the development of dysphagia

At oesophagoscopy severe ulceration was present in the oesophagus.

recumbent position during a barium meal examination and noting the reflux of barium into the oesophagus while slight pressure is applied to the abdomen. The examination will also reveal the presence of a gastric mucosal pattern above the level of the left leaf of the diaphragm * The severity of symptoms depends on the degree of gastric reflux rather than on the size of the herniation of the stomach if the hiatal hernia is associated with a normally placed cardia the symptoms may be slight or absent and this is often noted in what is sometimes termed a para-oesophageal hernia (Fig 26 10)

Treatment of hiatal deficiency The selection of patients depends largely on the severity of the symptoms and the appearances of the oesophagus when studied through

* This may be misleading if the condition is associated with a gastric lined oesophagus

the oesophagoscope If all patients with hiatal deficiency were operated upon the demand for surgical beds would be high, for the condition is an extremely common one far exceeding that of cholecystitis Patients with milder symptoms are treated by dietetic measures, alkalies to relieve gastric acidity and the use of the propped-up position at night If heartburn and regurgitation are severe an oesophagoscopy should be carried out if this reveals a reddened oesophageal mucous membrane with areas of erosion or leucoplakia, operative repair is certainly indicated Disabling dyspepsia and pain are further indications for surgery and the evaluation of the severity of the symptoms is not always easy Haematemesis and melaena are important pointers to the need for repair Actual ulceration of



FIG 26 19—The type of hiatal hernia often referred to as "para-oesophageal"

In spite of a large hernia there were no symptoms of oesophagitis The picture on the right was taken after the patient had been in the Trendelenburg position for several minutes and no oesophageal regurgitation has taken place The oesophagus has a large curve and enters the stomach obliquely The symptoms were those of upper abdominal discomfort after meals but there was no heartburn

the elevated portion of the stomach is not common, at oesophagoscopy the surgeon must be on the alert for Barrett's ulcer, as mentioned elsewhere this is one-tenth less common than peptic ulcer of the oesophagus Its treatment is quite different

The operation The thoracic approach with the patient under intratracheal anaesthesia supplemented by curare is the ideal it provides a better approach than the abdominal one to the seat of weakness, namely the posterior wall of the oesophageal hiatus, and there are no obstructions in the way, such as the left lobe of the liver, and no need for a difficult dissection at the depths of a laparotomy incision Through a thoracic approach the oesophagus is lifted out of its bed, the hernial sac cut away and the oesophageal hiatus easily defined and cleared of its areolar and serous covering the reduction of the hernia and the repair of its wall is readily executed by the manœuvres practised by Allison under easy vision and without the need for any deeply placed retractors

The left chest is opened widely through the interspace between the seventh and eighth ribs The lung which is kept well inflated throughout the operation is held away by pressure on a large moist swab the ligamentum latum pulmonis is divided and the oesophagus, after being thoroughly defined and cleared, is lifted upwards by means of an encircling

linen tape The oesophageal hiatus is then cleared thoroughly by scissor dissection of its serous coverings this dissection must be carried down posteriorly till the loop of the right crus is seen clearly to the full extent of its encirclement of the oesophagus the gap between the right and left components of the right crus will be obvious

A small incision is then made through the tendinous portion of the diaphragm A finger is passed up from below into the hiatus and it will emerge into the posterior

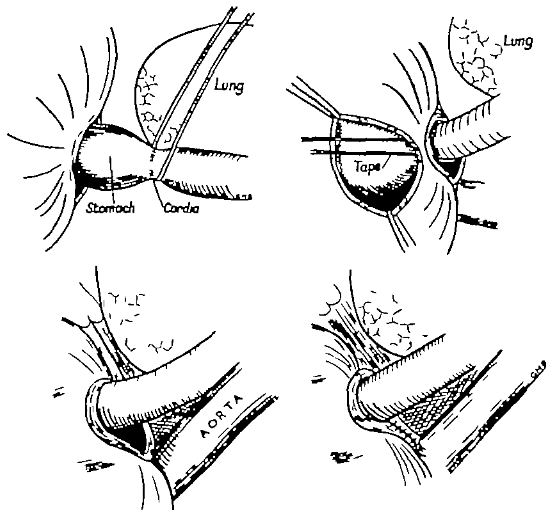


FIG 26-20 —Steps in the repair of hiatal hernia by Allison's method

( ) The oesophagus has been lifted up by a tape
(b) and ( ) Through a small incision in the diaphragm a finger has been placed int the sac which has been cut aw y the oesophagus is dra n down into the abdomen by traction on the previously placed tape and the hernia of the stomach reduced
(d) The gap in the posterior part of the right crural ring has been displayed and then closed with interrupt d thread or silk sutures.

mediastinum covered by peritoneum (the sac of the sliding gastric hernia) and the stretched phreno-oesophageal ligaments the sac is opened and freely divided along its whole periphery When this has been done a pair of Moynihan's cholecystectomy forceps is passed through the diaphragmatic incision through the hiatus and picks up the linen tape that has been passed around the oesophagus Traction on this tape reduces the lower end of the oesophagus well into the abdomen and at the same time lifts it up a little so that the posterior margins of the crural ring are seen clearly (Fig 26 20)

The cut edges of the peritoneal sac and the divided phreno-oesophageal ligament are then sutured to the peritoneum on the under-surface of the diaphragm to repair the ligament that anchors the stomach and which has been stretched by the herniation into the thorax

The important part of the operation follows this is the approximation of the divaricated muscle masses of the right crus by a few interrupted linen thread sutures these must

not be tied so tightly that atrophy of the muscle would follow The placing and tying of these sutures convert the V-shaped divarication into its normal Y shape The approximation of the fibres should be such that the tip of a little finger can be scarcely admitted between it and the oesophagus The ideal repair should cause slight dysphagia which persists for two or three weeks.

The tape which has been holding the oesophagus down into the abdomen is then removed and the diaphragmatic wound repaired by interrupted thread sutures The chest is closed in the usual way, and the lung fully re-inflated In our series we have not used intrapleural drainage, any post-operative effusion being aspirated in no instance has pleural effusion, or lower lobe atelectasis, been a factor of any serious importance

Criticism of other methods of repair. The repair of the deficiency through an abdominal approach is technically more difficult than through the thorax, because of the necessity to pack off the stomach and intestines and the access to the posteriorly placed deficiency in the hiatal opening is more difficult, the descriptions of methods in which the hiatal opening is diminished in size by suture of the anterior edge of the hiatus to the ligaments in front of the vertebral column are puzzling because they fail to leave a pliable muscular pinch-cock mechanism in the crural ring The use of fascia lata tends to produce a rigid hiatus but has been extremely effective in the hands of Harrington who has a vast experience of diaphragmatic surgery

Surgical treatment of the gastric lined oesophagus "The oesophagus lined with gastric mucous membrane" or the "congenital short oesophagus" (Barrett, page 441) is subjected to the risk of true ulcer, oesophagitis or stenosis Its diagnosis is not simple and depends on the correlation of radiological and oesophagoscopic findings The ulcerative process typically is seen *below* the normal epithelium of the oesophagus and biopsy shows this area above the ulcer to consist of gastric mucosa These ulcers, unlike those of true peptic ulcer of the oesophagus may perforate into the pleural cavity or into the aorta, unlike those of oesophageal ulcers They may respond to medical treatment

If they cause stenosis, treatment is by extensive oesophagectomy followed by oesophago-jejuno-gastrostomy, oesophago-jejunostomy or by oesophago-gastrostomy (page 444)

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CHAPTER 27

SUBPHRENIC ABSCESS

The surgical aim in the treatment of subphrenic abscess is to drain the pus without transgressing the main pleural and peritoneal sacs (extraserous drainage) Barnard (1908) showed conclusively that high mortality rates followed disregard of this principle and Harley (1949) has produced evidence recently which confirms the value of extraserous drainage Faxon s (1941) statement that inadvertent contamination of an uninvolved serous cavity during the drainage of a subphrenic abscess more than doubles the mortality rate indicates the need for a scrupulous selection of the site for drainage

Chemotherapy and antibiotic substances can probably sterilize an early subphrenic cellulitis but more usually they damp down the virulence of infection in these spaces and enable a patient to linger in chronic ill health for many months Chronic subphrenic abscess may be difficult to diagnose and is increasing in frequency because antibiotic therapy has lowered the death rate in the early stages The absence of notable fever and of leucocytosis in the group is a peculiar feature often responsible for delay in or lack of accurate diagnosis The management of proved abscess is complicated by the considerable coincidence of thoracic complications such as pleural effusion, lung infection (abscess atelectasis or suppurative pneumonitis) and empyema and by a not infrequent involvement of more than one subphrenic compartment by the suppurative process

Etiology of subphrenic abscess Apart from trauma such as thoraco abdominal war wounds the focus of infection usually lies in the abdominal cavity with general peritonitis secondary to acute appendicitis or perforated peptic ulcer as the most frequent source empyema development is a secondary feature due most commonly to faulty surgical technique in the drainage of the infra-diaphragmatic abscess but occasionally to an upward spread of infection or following a serous pleural effusion complicating the collapse of a lower lobe of the lung during the course of the abdominal illness Actual perforation of the diaphragm by a subphrenic abscess can occur and Harley (1949) recorded 15 examples of this in his collection of 182 cases Ochsner and de Bakey (1938) in reviewing 3 533 cases found that in only 2 5 per cent was the original infection in the thorax

Occasionally subphrenic abscesses develop in the absence of any detectable antecedent peritoneal infection and are possibly blood borne as in the instance of the staphylococcal perinephric abscess which notoriously follows some two to three weeks after a boil or carbuncle has been present elsewhere This type should be suspected in any obscure example of pyrexia of unknown origin for once considered its detection is often simple after clinical and radiological investigation. Harley described 17 such patients with a primary abscess in his large series and it is of interest to note that they represented the group with the lowest mortality rate (23 5 per cent)

Liver infection as a cause of subphrenic abscess A liver origin is present in about one-tenth of the patients except in tropical countries where the incidence may be considerably higher because of the frequency of amoebic abscesses Since the war this fact is of importance for scattered throughout every chest clinic is the history of the ex serviceman who has been under investigation for a chronic cough with expectoration Fig 27 5 is the radiograph of the chest of an ex-soldier with a humped diaphragm and changes

in the right lower lobe who was referred as suffering from carcinoma of the lung because of haemoptysis He was treated twenty years previously for amoebic colitis Such a condition due to an amoebic abscess that has ruptured through the diaphragm into a bronchus will not be diagnosed if "typical" anchovy pus is expected, for the secondary infection so often present alters the naked-eye appearance and the greatest importance should be attached to a history of service in an amoebic area As described later, the diaphragm usually shows a characteristic shape and amoebae may be detected in the sputum In several instances the diagnosis has not been made until a pathological examination of an operation specimen after lobectomy has been performed for a chronic lung abscess or for bronchiectasis

Apart from this group of immediate post-war interest, subphrenic abscess may follow liver abscesses, the result of suppurative cholecystitis or suppurative pyelephlebitis The abscess is often a terminal complication to an illness characterized by high pyrexia, rigors and jaundice, and this type, as would be expected, causes a high mortality rate

Subphrenic abscess due to malignant disease in the abdomen Carcinoma of the stomach or pancreas is sometimes the cause of subphrenic abscess and this is more frequent on the left than right side, accounting for a higher mortality rate there than in the right-sided abscesses Harley described 50 left-sided abscesses in a series of 182, and in addition to these, 10 were bilateral abscesses, the mortality rate being 50 per cent on the left as compared with 31 per cent on the right side

Subphrenic abscess as a complication of mediastinitis or spinal osteomyelitis Acute osteitis of the vertebrae is a very unusual cause of subphrenic abscess and because of the obscure symptoms may be overlooked as a complication of mediastinitis it is usually a terminal event

The chronic "missed" abscess An unsuspected, undiagnosed subphrenic collection of pus often producing chronic ill-health, frequently with a profound anaemia often without leucocytosis, may exist for months Its presence may be declared by its natural proximity to the surface or by its rupturing through the diaphragm into the lung the latter egress may produce a confusing diagnostic picture which may receive the label of lung abscess, empyema, bronchiectasis or pulmonary tuberculosis Surgical treatment of the thoracic condition may provide the first suggestion that the origin of the suppuration is infra-diaphragmatic, for pus may be found oozing through a diaphragmatic perforation

Subphrenic abscess after wounds Wounds that traverse the pleural and peritoneal cavities may produce infective processes above or below the diaphragm of 126 thoraco-abdominal wounds 12 developed subphrenic abscess (Blackburn and d'Abreu, 1945) Half of these patients had coincident pleural empyema, and in two, lipiodol instilled into one abscess cavity found its way through the diaphragm into the other one, while in the remaining four, when the chest was opened for the drainage of an empyema, pus was seen welling up through a perforation in the diaphragm All of these patients except one survived, both the supra- and infra-diaphragmatic collections being drained when a double infection existed In addition to these twelve patients, seven others with right-sided liver wounds developed pleurobiliary fistulae followed in each instance by an empyema drainage of the empyema was followed by recovery in all with spontaneous closure of the liver fistula

Anatomical features of subphrenic abscess. The localization of abscesses in the sub-diaphragmatic compartments after abdominal infection is dependent on anatomical factors and the laws of physics These spaces are divided into right and left compartments, which are themselves designated as supra-hepatic or infra-hepatic (Harley, 1949) for practical purposes there are two intraperitoneal sacs on the right and three on the left, the

bare area of the liver forming the lower boundary of the one extraperitoneal space while the extra space on the left is the lesser peritoneal sac Academically another extra peritoneal space lies behind the bare area of the oesophagus and above the left supra renal body

The right supra hepatic space is closed posteriorly by the upper layers of the coronary and right triangular ligaments The lower layers of these ligaments form the upper border of the right infra hepatic space (Morrison s pouch) This simplification of the right supra hepatic spaces is anatomically correct and clinically helpful. An appreciation of it enables a good appraisal to be made of the differences in signs and symptoms that accompany the development of abscesses in the right supra and infra hepatic compartments the thoracic symptoms predominating when infection involves the area above the liver

It is pertinent at this stage to enquire into the reasons for infection spreading into these two right-sided compartments as abscess formation here is more than twice as common as on the left side

In the course of a peritoneal infection the resultant effusion will gravitate to potential spaces such as those under discussion and into the pouch of Douglas and there is evidence that the pressure is more negative in the upper than lower abdomen, especially during inspiration the localization of fluid collections will depend on the nursing posture adopted and on the suction action of the diaphragm and the intestinal movements if the gut becomes distended by gas as is the rule in paralytic ileus the fluid will be displaced along natural channels such as the paracolic gutter Just as air introduced accidentally or deliberately as in therapeutic pneumo-peritoneum reaches the subphrenic compartments so too will fluid and once the surface tension between the liver and the diaphragm has been broken fluid will occupy the potential spaces The subsequent local response to inflammation will produce confining adhesions

The presence or absence of air in a subphrenic abscess depends on the nature of the organism which may be gas producing or on the presence of an air leaking intraperitoneal lesion Air is present only in 30 per cent of subphrenic abscesses on radiological examination

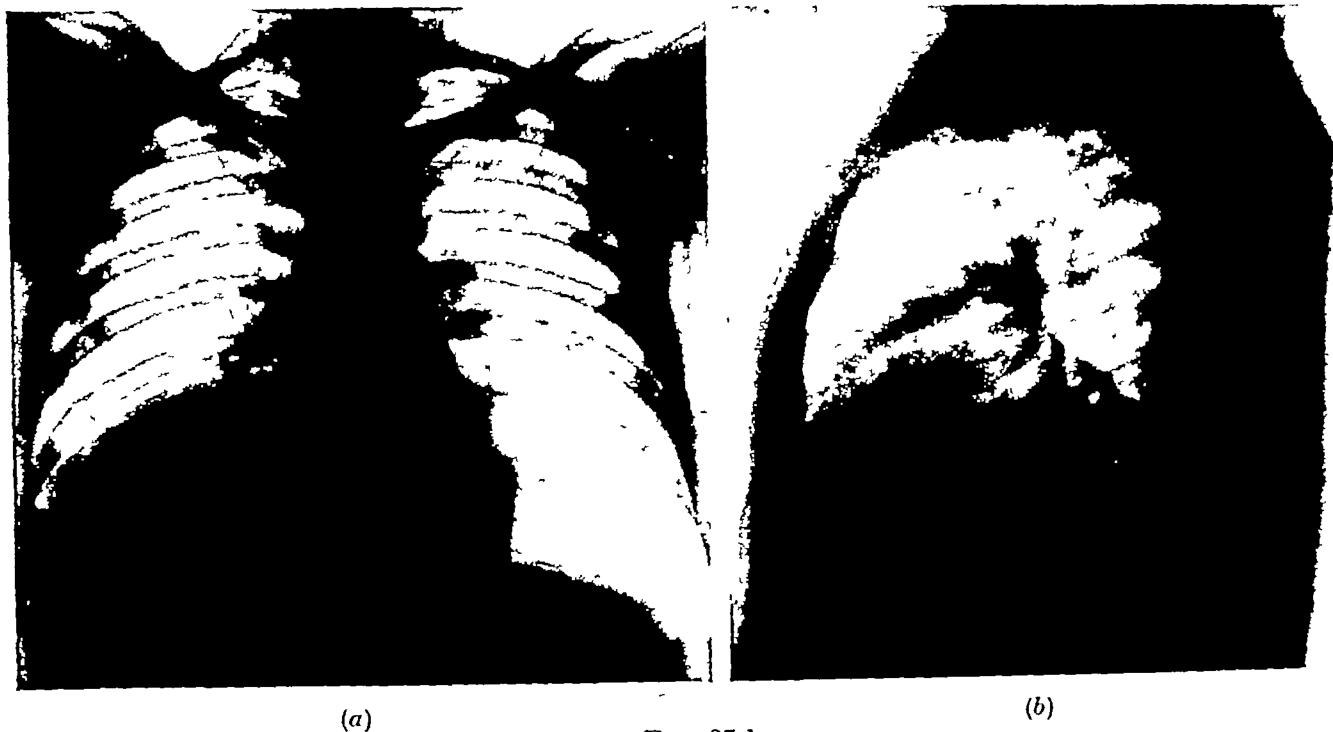
The right-sided predominance is naturally explained by the greater frequency of foci of infection on that side of the abdomen the result of perforated appendicitis and the complications of diseases of the gall bladder and duodenum

Diagnosis of subphrenic abscess The gradation of symptoms and signs from an obvious classical onset some ten to twenty days after a recognized operated abdominal catastrophe such as appendicitis or a perforated peptic ulcer or following a procedure such as partial gastrectomy to a far from dramatic and insidious onset emphasizes the lack of a typical pattern. Pyrexia and a leucocytosis so typical of the rapidly diagnosed abscess complicating an abdominal operation may be lacking in a truly chronic abscess patient who may be ambulant yet suffering from persistent malaise exhaustion anaemia and often a chronic cough

Three-quarters of the patients have thoracic and abdominal symptoms in addition to the general constitutional disturbances the remaining quarter may have abdominal symptoms only or solely thoracic ones Those with combined symptoms often have diminished chest and abdominal movements with a typical referred phrenic nerve pain in the shoulder in the early stages Pleural effusion and collapse of the lower lobe on the side of the abscess may pass on to empyema and lung abscess with the further complication of a bronchial fistula through which pus is inadequately expectorated often after a small haemoptysis A history which includes these complications after an abdominal illness or following a laparotomy will suggest the diagnosis but in a thoracic clinic a number of

patients are admitted with a drained empyema which has failed to improve because the underlying subphrenic abscess is still present (see Fig 27 7 (*a*)), and it may be said here that if empyema and subphrenic abscess are coincident both require separate drainage, for no reliance can be placed upon Nature's spontaneous effort to provide trans-diaphragmatic drainage whether the fistula be into the pleura or into a bronchus

In supra-hepatic abscesses both on the right and left side the thoracic symptoms predominate with serous effusion as an early complication of great diagnostic value, but abscess in the right sub-hepatic space or in the lesser sac will not usually give thoracic signs



(*a*) (*b*)

FIG 27 1

(*a*) Right posterior subphrenic abscess with characteristic diaphragmatic rise

(*b*) Lateral view

Note 'peaking of diaphragm"

and symptoms, pyrexia, ill-health and leucocytosis often accompanying a detectable mass in the abdomen

Radiological diagnosis By no means infallible, radiological examination by screening and by postero-anterior and lateral films is the most important single examination leading to successful diagnosis As pleural effusion is common, penetrating films are essential and may give more valuable information than screening, which, however, should never be omitted Usually the diaphragm will be elevated, immobile and thickened The elevation may be localized or general. but if a localized elevation is noted the characteristic hump always overlies the abscess (Harley) Generalized immobility of a normal thin leaf is by no means diagnostic of a subphrenic inflammation, for this may be noted after many abdominal operations in the first few post-operative days and is very characteristic of amoebic hepatitis without suppuration But a thickened, immobile diaphragmatic leaf is very significant Associated thoracic changes due to pleural effusion and collapse of a lobe or segment are strong supporting evidence of a supra-hepatic abscess

Below the diaphragm the presence of gas is of great diagnostic assistance but is only present in some quarter of the patients. it may well be overlooked on the postero-anterior

view and is more readily detectable in the lateral picture It may be confused with the normal gastric air bubble on the left side

In suspected left-sided abscess a barium meal may help the abscess producing displacement of the body of the stomach

Exploratory needle aspiration As a diagnostic measure this has little to commend it and in recent years has been condemned because of the grave risk of contaminating the pleural cavity The long maintained assumption that in a subphrenic abscess the rise of the diaphragm is soon followed by adhesive obliteration of the costo-phrenic sulcus is quite untenable as any who have had the misfortune to open accidentally the pleural cavity



FIG 27 2.—A well-defined and humped elevation of the left diaphragm due to a subphrenic abscess that was drained.

well know Aspiration immediately before operation, on the table is generally dangerous and should be confined to the exploration of a suspected serous pleural effusion as a diagnostic measure to establish the presence or absence of an empyema and possibly for the injection of a prophylactic dose of an antibiotic If a careful clinical and radiological examination has indicated the presence and probable site of an abscess an exploratory operation not only lessens the risk of contamination of the pleura but is more likely to discover an abscess that the needle may have failed to detect The main objection to needling however is that the natural tendency to incise down along the line of the needle that has successfully encountered pus will often lead to a transgression of the pleural cavity for in spite of many ingenious suggestions in the literature that the pleura if not obliterated should be sutured such a manœuvre is frankly quite unreliable

Treatment Although a considerable number of infections in the subphrenic area probably subside before the suppurative phase under full antibiotic and chemotherapy treatments established suppuration should be treated by drainage The operative approach to these spaces is not easy except through a risky trans-diaphragmatic incision after resection of a rib posterolaterally for the evacuation of pus in the right supra hepatic

compartment It is unwise to rely on an adhesive obliteration of the costo-phrenic sinu even when the diaphragm has been grossly elevated as a result of the abscess, and th dangers of empyema formation are considerable if the old routine approach is adopte Moreover, all statistical enquiries (Faxon, 1941, Ochsner and de Bakey, 1938, Harle 1949) prove that a transpleural drainage has always carried a higher mortality rate tha an extraserous approach

Harley (1949) has effectively demonstrated the dangers of draining a subphrenic absce across the free pleural cavity or the general peritoneal cavity and has reiterated the teachin



(a) (b)

Fig 27 3

(a) Right anterior subphrenic abscess with fluid l Complication of sutured perforated duodenal ulcer

(b) Lateral view of subphrenic abscess illustrated in

of Barnard He found that of 42 patients drained by the ex cent) died, in contrast with 27 deaths (33 per cent) in 83 c or general peritoneal spaces

The anterior route Abscesses in the lesser sac and in Rut space can be opened anteriorly without encroaching on the and rarely produce signal difficulty The best approach is cutting incision for the supra-hepatic abscess and by a paran gastric abscess in the lesser sac

The posterior extraserous approach (the Ochsner operat replace any higher attempt at drainage by resection of the el twelfth rib is resected sub-periosteally, the muscles attached the fascia beneath the posterior layer of the rib periosteu upper part of the peri-renal fascia is exposed and displace of the diaphragm to the arcuate ligaments is carefully d upwards together with the lowest fold of the pleura blunt dissection behind the liver will be needed before are encountered and opened, good illumination and

ntam a dry field are valuable the abscess is opened widely and a large-bore tube in its cavity This tube is securely anchored by fixing it to the skin by adhesive pping fixed through a safety pin as in the method used for anchoring an open empyema age tube

In the post-operative course this tube must not be shortened until radiological studies ed out after the instillation of lipiodol have demonstrated clearly that the abscess have collapsed and that nothing more than a tube track remains premature shorten r removal of the tube before adequate drainage has been ecured may lead to loculation questration of the abscess cavity



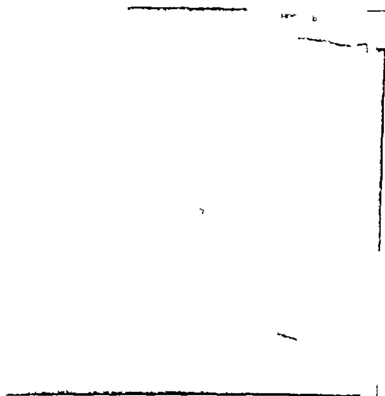


Fig 27 4 Fig 27 5

Fig 27 4 —Lipiodol sinogram after drainage of subphrenic abscess. The ca ty still requires tube drainage

Fig. 27·5 —Amoebic abscess of liver with rupture into right lower lobe with production of haemoptysis. Referred for examination as suspect carcinoma of lung because of shadow in left chest demonstrated on screening to be aortic enlargement. Proved case of amoebiasis which leared under emetine Had first suffered from amoebic dysentery *0 years ago.

Appropriate chemotherapy is combined with post-operative breathing exercises and blood transfusion should be used if the haemoglobin falls below 70 per cent In the post-operative period a constant watch must be maintained for the development of subdivisions of the abscess inadequate drainage extension of infection to other subphrenic spaces empyema development or atelectasis with possible septic pneumonitis or lung abscess formation

Treatment of thoracic complications

Pleural effusions Serous effusions are common their benign sympathetic nature can only be established or disproved by the use of the aspirating needle If the underlying abscess is satisfactorily drained the effusion will absorb rapidly If at the time of drainage of the subphrenic collection a thoracic paracentesis reveals a turbid fluid this

should be aspirated and penicillin instilled, the future management being along the lines of an infected pleural effusion (see Chapter 6) If a frank empyema is present and the indications for drainage are present, this is executed as if no subphrenic abscess were present, both collections of pus being drained separately through the appropriate anatomical site

Atelectasis The prompt recognition of this and its energetic treatment by postural drainage combined with chemo- or antibiotic therapy will often be followed by re-expansion if the subphrenic abscess has been adequately drained If the lobe does not re-expand



Fig 27 6—Radiograph of a patient twelve weeks after a pelvic abscess had been drained Constant pyrexia and cough The hump in the diaphragm indicates a typical subphrenic abscess There is also an inflammatory condition in the right lung

after twelve hours then bronchoscopic aspiration under local anaesthesia should be done, as the cough mechanism may be too weak to clear the bronchi of the occluding mucopus Neglect to secure rapid re-expansion will leave the patient in danger of developing a lung abscess, a pneumonitis or later bronchiectasis, neglect of this thoracic complication has undoubtedly been partly responsible for the high mortality rate of subphrenic abscess even after adequate surgical drainage If a lung abscess develops it is treated as outlined in Chapter 7

Treatment of subphrenic abscess due to hepatic amoebiasis Perhaps the greatest single diagnostic aid in recognizing this condition is knowledge of the fact that the patient lived for a time in an area where amoebiasis existed A history of dysentery, followed by a pyrexial illness, accompanied by cough with expectoration of purulent sputum should lead to an accurate diagnosis but amoebiasis is notoriously unfaithful to classical clinical patterns and the history of dysentery may be absent If the condition is diagnosed, however gross the thoracic signs and symptoms may be, surgery is withheld until a full course of anti-amoebic therapy has been instituted

Aspiration of an amoebic abscess should not be practised unless the routine course of treatment has failed and direct open drainage will only be instituted if the aspirated fluid reveals secondary infection by organisms usually of the coli typhoid group

Treatment of the late chronic inadequately drained abscess The relative infrequency of subphrenic abscess is undoubtedly the reason for its late recognition and imperfect treatment and a small group of patients will be referred to thoracic clinics in an unsatisfactory clinical condition Some of these patients have undergone rib resection for an empyema that has followed a major abdominal operation and not infrequently the over riding thoracic symptoms conceal the exciting cause of such namely a subphrenic abscess usually in the supra hepatic compartment Pyrexia general ill health cough and thoracic pain lead to the clinical detection of a poorly moving chest wall with the underlying physical signs of a pleural effusion. An associated collapse of the lower lobe may be overlooked The changes of the pleural effusion from a clear serous fluid to a purulent exudate is not uncommon and a rib resection for drainage of the empyema may follow without treatment being accorded to the subphrenic abscess or to the collapsed lower lobe the constitutional disturbance and the pyrexia will therefore continue In such a disheartening state of affairs the burdens of the ill patient may be increased by a despairing withdrawal of the chest drainage tube a chronic empyema being added to the inadequately drained areas of infection A fresh mind approaching this dismal sequel starts with the opportunity of grasping the essential features of a prolonged illness in such a history the greatest assistance will be provided by the elucidation of an initial abdominal cause to the train of events The following history is characteristic

B P a girl of 14 was operated on elsewhere on August 26th for an appendix abscess drainage was adopted as a course preferable to the removal of a gangrenous adherent appendix situated retro-caecally Progress was never satisfactory a low pyrexia continued for three weeks and she remained toxic ill and apathetic The temperature continued to swing in spite of a long course of penicillin, and sulphamethazine streptomycin was then given for a week with no effect Eleven days after the appendix abscess had been drained a radiograph demonstrated elevation of the right diaphragm and some right pleural effusion Three days later complaint was made of severe right-sided chest pain and on that day a resection of a portion of the ninth right rib was followed by the drainage of purulent fluid from the right pleural cavity

Closed drainage of this pleural effusion continued for two weeks until it was replaced by an open tube pyrexia persisted On November 1st a radiograph showed a collapse of the right lung covered by a thick visceral pleura and a fluid level at the bottom of the pleural cavity a resection of the tenth rib was carried out and open drainage re-instituted. She continued to deteriorate with no relief of pyrexia

She was admitted to the Hospital by transfer on November 25th three months after the original abdominal operation She was an ill, toxic and dispirited child with a temperature of 102 The right chest was rigid and flattened and a little pus oozed from the two previous empyema drainage sites. The blood picture was R B C 3 900 000 Haemoglobin, 86 per cent—11 9 gm per cent White blood cells 30 700 (in the differential count 84 7 per cent of these were poly morphonuclear leucocytes)

The clinical features of a right pyo pneumothorax were confirmed by a radiograph which also showed a high right diaphragm The pre-operative diagnosis was right pyo-pneumothorax and subphrenic abscess.

On 30th November a right major thoracotomy was done through the bed of the resected fifth rib with an accompanying blood transfusion and under general intratracheal anaesthesia A large quantity of pus was evacuated and the imprisoned lung completely freed by an extensive decortication.

The twelfth rib was resected and the abscess drained by Ochsner s method a large tube being left in the cavity The post-operative progress was rapid with immediate remission of the



(*a*)



(*b*)

FIG. 27 7

(*a*) Radiograph of the chest of a child of 14 years three months after appendicectomy
There is a right pyo-pneumothorax and a raised diaphragm

(*b*) Radiograph two days after decortication of completely collapsed right lung and drainage (extraserous posterior route) of subphrenic abscess
Operation by Mr Robert Brain



FIG 27 8 —An empyema and subphrenic abscess have been drained separately
The sinograms indicate need for continued drainage of empyema pocket but the tube in subphrenic abscess can be removed

temperature the lung re-expanded within 24 hours and the thoracic tube was removed a day later (see Fig 27 7 (*b*))

The subphrenic abscess drained well but required tube drainage for four weeks The patient was out of bed a week after the operation and was discharged 32 days after admission well and afebrile

The essentials in treatment of an empyema coincidental with subphrenic abscess are that each cavity must be given separate drainage and that the empyema must be treated on its own merits

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